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DEVELOPMENTAL ASPECTS OF HIERARCHAL CONCEPT ATTAINMENT. FINAL REPORT.

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THE PRINCIPAL OBJECTIVES OF THIS STUDY WERE (1) TO DESCRIBE DEVELOPMENT STAGES OF STUDENTS FROM FIRST- THROUGH NINTH-GRADE LEVELS AS THEY AFFECT THE SOLUTION OF A THREE-DIMENSIONAL CLASSIFICATION PROBLEM, (2) TO UTILIZE THE INHELDER-PIAGET AND THE BRUNNER SYSTEMS OF DESCRIBING STAGES OF COGNITIVE DEVELOPMENT, AND (3) TO DETERMINE BY MULTIVARIATE ANALYSIS IF DIFFERENCES IN DEVELOPMENTAL STAGES ARE RELATED TO VERBAL AND NONVERBAL OR PERFORMANCE APTITUDES. SUBJECTS OF GRADE LEVELS 1 THROUGH 9 (360) SORTED 54 OBJECTS (VARIED SIZES, COLORS AND SHAPES) INTO A 3-DIMENSIONAL MATRIX, WITH MOVEABLE BOXES OF 3 LEVELS, 3 ROWS AND 6 COLUMNS. AN ADDITIONAL GROUP OF SUBJECTS RECEIVED DISCRIMINATION TRAINING ON THE OBJECTS. THE RESULTS SHOWED THAT SIGNIFICANT AGE-RELATED INCREASES IN SCORES OCCURRED, FIRST FOR COLOR, THEN SIZE, AND THEN FOR FORM. HORIZONTAL SCORES PRECEDED VERTICAL. THERE WERE NO SEX DIFFERENCES IN ANY OF THE GRADES OR TASKS. THE USE OF LARGE OBJECTS IN EARLY SORTING GAVE EVIDENCE OF "CONCRETE" RESPONSES EXTENDING INTO THE NINTH GRADE. "SCANNING" STRATEGY WAS LATE IN DEVELOPING. DISCRIMINATION TRAINING SIGNIFICANTLY INCREASED THE SCORES. (JC)

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DEVELOPMENTAL ASPECTS OF HIERARCHAL CONCEPT ATTAINMENT

FINAL REPORT

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of Hierarchal Concept Attainment

ABSTRACT

Students of grade levels 1-9 inclusive (N=360; equal for sex) sorted 54 objects which varied in size, color, and shape into a hierarchal, three-dimensional matrix, with moveable boxes in trays in three levels, including three rows, and six columns. An additional group of 10 Ss at each grade received discrimination training on the objects.

The results showed that significant age-related increases in scores occurred, first for color, then size, then for form. Horizontal scores preceded vertical. There were no sex differences in any of the grades or tasks.

The nature of the overall task required logical structure as well as concrete sensory ordering. The use of large and familiar objects in the early sorting gave evidence of "Concrete" responses extending strongly into the 9th grade. The logical solution, requiring "scanning" strategy, was late in developing. Students strongly tended to "center" or "focus" on only parts of the problem, as evidenced by the gradually rising scores. There was evidence of small positive correlation between spatial ability and vertical sorting scores.

Discrimination training significantly increased the scores.

Only 9th graders and adults, both especially trained on discrimination of the objects used, and also on the structure of the matrix, showed the ability to achieve a full solution.

The problem itself seems best adapted to ages nine and over.

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DEVELOPMENTAL ASPECTS OF CONCEPT ATTAINMENT

David R. Stone

The processes of perception and cognition, which underly this study, are receiving increasing attention, (Dember, 1960; Anderson and Ausubel, 1965; Wohlwill, 1962). Since such processes have relatively unique application to human learning, they seem of particular importance to education. The transfer capacity of the human is due principally to his ability to "store" information in the form of verbally coded representations (Miller, Galanter, and Pribram, 1960) sometimes called concepts. The use of coded symbols to represent information about object categories has been described by Shephard, Hovland, and Jenkins (1961).

In this report we are including a somewhat broader coverage of the literature than is usual for many projects because of the need to develop more context here than for problems in a more established field. This context should be informative to the patient reader. It may be scanned in favor of the findings and discussion section by the busy reader.

For orientation, certain basic terms will also be defined as used in this research area, and in this study.

PART ONE: PROBLEM CONTEXT AND FOCUS

The Interpretive Process

When a learner responds to a stimulus, a complex of processes is involved. Broadly, the interpretive process (Cronbach, 1963) is a way of making intellectual use of incoming data. At least two stages are involved, and two levels.

Stages

The two stages, as used here, are perception and cognition. Figure 1.1 gives an illustration or model of the possible relationship between perception and cognition, both considered as interpretive processes.

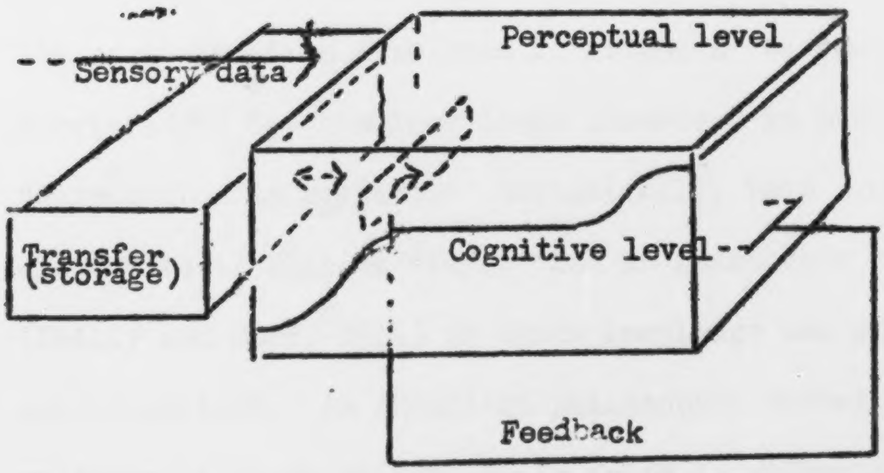

Sensory data
Perceptual level
Transfer (storage)
Cognitive level
Feedback

Figure 1.1 Perceptual and cognitive stages in interpretation.

The most complete description of these stages is given in Bruner's observations (1957) on "going beyond the information given," and his (1957) careful description of perceptual readiness. Bruner describes how the learner takes sensory stimulus information, and goes beyond it by supplying mental "structure." The structure is first a mental grouping of recurrent stimuli with similar characteristics. It depends on feedback from experience, and transfer or utilization of learned material. This factor or hypothetical learning construct is called "L" by Spence (1950). It appears to be both non-verbal (perceptual), and verbal (cognitive.) The act of catergorizing recurrent stimuli is, according to Bruner, the first evidence of thinking. In a sense, it is similar to Mead's (1934) comsign, except that Mead requires the "meaning" to be shared with another organism, a distinction also seen in Piaget's "egocentric speech." Morris (1946) has combined these processes in his phrase, "disposition to respond." Historically, this process was alluded to in Plato's "Forms" and in Leibnitz's "Monads," (Thilly and Wood, 1951) in which knowledge was abstract, and self-contained. An excellent philosophic description of the relation of words to reality is found in Wilbur M. Urban (1939). Korzybski(1933) places great stress on the "silent" perceptual levels as a way of keeping in contact with reality, while Urban favors language, particularly the metaphor, as a "molder" rather than a cloak for reality. Instead of defining creativity as a return to primitive perceptual levels, it may be possible to see creativity as (1) a kind of "chunking" (Miller, 1956), (2) a re-structuring of verbal units, or (3) a "hold" process utilizing "decision trees" (Hunt, 1962, chap. 8) in which verbal structures catalyze each other.

This critical stage, where shifting sensory data is stabilized, appears to be the bridge between perception and cognition. It is here that dynamic sensory processes are transformed into static processes. Wohlwill (1962) describes a change from "perception to inference." However, where one process ends and the other begins is not yet well defined. Bruner and Olver (1963) refer to labeling as the stage of cognitive transformation. Operationally, then, we may make the verbal label the dividing line. The degree to which this coding is conscious or unconscious, pre-verbal or verbal, intuitive or concrete, automatic or intentional, must await further research. In the meantime, it is reasonable to see a general relationship in the terms, coding, information processing, verbal mediation, semantic generalization, concept, concept attainment, concept formation, schemata, and verbal habit-family hierarchies. All are attempts to explain what goes on in "The black box" of the mind. In effect, these "cognitive transformations" produce "cognitive equivalents" or labels which represent perceptual reality. The word "concept" is thus a synonym for cognitive equivalent.

Levels

Since the degree of awareness on the part of subjects varies in experiments like the current one, levels of awareness must be considered. When the individual begins to respond to recurrent regularity, he does so with varying degrees of awareness. Even when ready-made verbal label are available in the culture, the degree of awareness may vary (Vygotsky, 1962). Osgood's (1953) criticism of Hull's (1921) definition of concept development, is an illustration of the problem. Osgood maintained that when Hull defind a concept as an "abstraction of common stimulus elements in a series of stimulus objects," that such applied to any learning, not just concept learning. Osgood further pointed out that there is a real doubt that rats respond to "triangularity" as a concept, although they certainly respond perceptually to a range of discriminally different stimulus objects. The term, "stimulus generalization" is often used here, rather than "concept."

It appears then, that we have the above perceptual concepts as "silent," and in an addition, verbal concepts (Kendler and Vineberg, 1954). It is also apparent that some writers prefer to use the word "concept" only for the level of verbal representation using pre-concept for earlier levels. As Skinner put it (1957), "to know is to be able to talk about."

The problems relating to the description of perception and cognition are discussed at length, in developmental terms, in Werner and Kaplan's book Symbol Formation (1961). How operant conditioning is effective in the forming of verbal habit-families and word classes is described by Staats (1964). A binomial model is suggested by Suppes and Ginsberg (1963). Berlyne (1957b) has shown how S-R psychology and information theory gives many useful hypotheses for the studies of higher mental processes, but Ausubel (1963) maintains we need to go further into a description of "cognitive structure" for a more complete explanation.

As the individual becomes more able to utilize words, a "control layer" begins to override the simple perceptual or intuitive responses which have been formed by simple conditioning and association. Luria (1961) has described this in terms of speech regulation of behavior. For this present study, the implications are for careful experimental control of this verbal factor, since it becomes increasing influential with age. White (1965) in a careful analysis of the charge from simple associative responses through a "temporally stacked" response hierarchy, attempts to co-ordinate several diverse source materials into a theory of internalized control.

According to him, the first phase of the operation of this control layer seems to develop between the ages of 5-7. (A similar period is observed by White in Freud's observations regarding the internalization of sanctions.) White emphasizes that this higher level functioning, which he terms "cognitive," depends critically upon the inhibition of associative functions. These layers are seen as parallel but arranged in a competitive hierarchy in the child over seven.

In the present study, we shall attempt to describe how more primitive responses to color, size, and form, become refined, and subject to verbal, or logical control with increasing age. In Bruner's terms, a shift is seen from focusing to scanning strategy.

Experimental Interest in Cognition

The surge of interest in cognition, mentioned as a real need by Hebb (1960) is beginning to yield a variety of experimental results. Cognition is often used operationally as a synonym for thinking. It is a more advanced process than perception (Bartlett, 1958) in that perception is an awareness of immediate sensation, where (Bruner, 1957) cognition goes beyond the perceptual information given. These efforts seem to be clustering into three major trends.

(1) Verbal Mediation. The SR theorists have contributed in terms of describing the building of habit strength by stimulus-response association. Based on Pavlov, Guthrie,

Hull, and Skinner, (Hilgard, 1956), research studies in this area are demonstrating that verbal mediational processes may be described in terms of extended associations. There is, of course, some real question as to whether these are simple additive. For example, verbal habit family hierarchies and processes have been studied by Cofer (1965), Osgood (1957), and Goss (1961). In a sense, such studies are based on some form of semantic generalization (Razran, 1961) and (Maltzman. 1955).

In the present study, generalizations based on color, size, and form will be used.

(2) Information Processing. The organizing of "bits" of information approach to the explanation of cognition and concept development is described in detail by Attneave (1959) and Earl Hunt (1962). The storage aspect is suggested by Wechsler's "engrams" (1963). A considerable amount of experimental work by Restle (1958) and Bourne (1961) has indicated that there is a continuous incremental response to varied amounts of information. Bourne, for example, has shown that changing amounts of relevant and irrelevant information affects the acquistion or utilization curve. Based also to some extent on Hull, investigators here have a formula indicating continuous increments for each trial. This means that each response strengthens the tendency to respond.

Estes (1960) has maintained that "all or none" learning must be considered as well as the central S-R theory of "associative strength," "habit hierarchy," or "increased resistance." Anderson has (Anderson and Ausubel, 1965, Part III) described information processing as a cognitive opposition to "mediation" as proposed by the S-R behaviorists. His thesis is that sequential prior learning is not basic to cognition. This is another way of stating the "continuity-discontinuity" issue (see Goldstein, et all, 1965). Cognitive learning is, in this controversy, associated with "sudden" or one-trial learning, and continuity of conditioning experiences which build habit-strength. Ausubel (1962) has suggested a "subsumption" or hierarchal organization which may account for shifts beyond those expected in simple habit-strength systems. A hint of this is seen even the behavioristic Hull's (1952) "anticipatory goal response" mechanism. This is behavioristic cognition!

Mediation theorists, such as Spence (1950) challenge cognitive theorists to produce experimental proofs and cognitive theorists in effect say in criticism of their S-R opponents that if you deal with simple things you get simple answers.

(3) Developmental Analysis. One way to understand cognition is to observe its change with age. In this approach, careful descriptive data is sought, as free as possible from theoretical controversy.

The two major authorities in this area, Bruner and Piaget, have both described the course of cognitive growth.

The best summaries of Piaget are in Berlyne (1957), J.McV. Hunt (1961), and Flavell (1963). Piaget has over many years, described three major stages or periods: the sensory motor (0-2), the concrete (2-11), and the formal (11-adult). The concrete is sometimes further refined into pre-operational thought (2-4) intuitive thought (4-7), and concrete operational thought (7-11). In the Piaget conference, which he attended, (1964) Piaget described the periods as sensory motor, pre-operational, concrete operational, and formal. Bruner et al (1956) in A Study of Thinking, described concept attainment in terms of two general kinds of strategy, scanning and focusing. Concepts from Piaget and Bruner will be used to describe some of the trends observed in this study.

The General Problem of This Study

In the present study, the subjects for the major research ranged from 1st graders through 9th graders, inclusive. A small adult group was used later to begin to establish some upper parameters. The subjects were asked to respond to 54 blocks which varied in form, size and color. Their task was to sort the blocks into a 3 x 3 x 6 matrix. The matrix was set up in tray form. Each tray had a 3 x 6 set of compartments.

The subject was instructed to place one block in each of the 18 compartments in each tray. The three trays were stacked on each other, but pivoted so that the middle and bottom trays were easily accessible. More details regarding the materials will be given later under procedure.

Children in the present study are largely in the concrete-operational period. During this period, according to Piaget, seriation, grouping, and awareness of immediate sensory differences are actively developing. The ability to use logical variations (formal period) should also be beginning to develop. Experimental details on some aspects of this period have been provided by Bruner (1964) in his article, "The Course of Cognitive Development."

Since this study is particularly concerned with developmental aspects of concept attainment, more details in this area will be summarized in the specific review of literature.

Concept Development, Formation, and Attainment.

The definition of a concept is still subject to variation, but operational definitions have been developed to a usable degree.

When a race, or more properly, a culture is beginning to discover and differentiate aspects of its environment (Durkheim, 1915) the process of symbolizing is very primitive. For the early Greeks, the chemical world consisted of "earth, air, fire, and water." To observe the growth of the listing of elements in the Periodic Table in chemistry, for example, is to observe the growth of a complex of concepts, with accompanying symbols.

Is this "discovery" process similar within an infant growing up in a culture whose symbol-system is simple as compared to a complex system? Whorf (1941) indicates that where a culture has no apparent need to develop differentiating terms, distinctions are blurred and lost.

For our purposes, we will assume that the culture-concept development problem is not the same as the individual-concept development problem. The individual is given many short-cuts, and ready-made concepts as he interacts with parents, peers, and teachers. He does not discover in the original sense. Piaget has attempted to describe "original" schematizing, but we cannot ignore the "savings" provided by cultural influences. (Mink, 1964 in Piaget Rediscovered) Indeed, discrimination training so influences category-problem-solving, that instructions in an experiment such as the present one become critical factors which can mask more primitive or "natural" development. As will be seen, the primary objective of describing trends had to be protected against just this influence with the result that the second objective which requires verbalizing had to be minimized.

Whether or not verbal category-formation takes place from the concrete to abstract or reverse is a related issue. Brown (1958) and Brown and Berko (1960) indicate that the process may occur both ways, depending on cultural form. For example, some parents would say, "there is a bird," rather than, "there is a finch." Yet they would ask a child to get "an orange," rather than "fruit." The child often cannot state explicitly, what categories he is using, even when he is using appropriate labels (Church, 1961 pp. 70). Church states that upward categorization (classing two perviously non-related things together) seems to appear later in development than differentiation.

Kinds of Concept Problems.

Should the phrase "concept formation" or the phrase "concept attainment" be used? There is no standard form for this in the literature, despite the need to distinguish the original, first discovered concept, from its later internalization in a given individual.

We will use Earl Hunt's (1962, p.7) definition of concept learning as, "all forms of behavior in which the use of a name is learned will be included under the rubric "concept learning." We will use the term "acquisition" for this process. Hunt points out that a concept "former" is a discoverer in that he reorders objects into new equivalence classes. So concept formation will be reserved for the creative discovery of concepts, new to the culture. It is of course a kind of discovery when a child learns a culturally available concept, since it is new to him. In fact, Bruner uses the term "discovery learning" for the inductive teaching process. However, in the full sense, this is "re-discovery" learning, or better, concept attainment.

Piaget (1952) uses "concept" in a much broader sense; roughly in the same sense as the word "principle" is generally used. A statement of the relationships among concepts might then be referred to as principles. The word, "gravity," is thus a concept, but statements of the "law of gravity," or "laws of gravity" would be in the class of verbalizations to be called "principles."

It could then be further proposed to call concepts, "equivalence transformations," and principles, "analytic transformations." Both of these products are then a result of what could be called problem solving, Type I (units), and problem solving, Type II, (hierarchal taxonomies). Units such as letters, being subsumed into words and sentences (for example, category-formation labels as equivalence transformations) would then be Type I, and statements of their inter-relations would be Type II. Statements of causal relationships and principles of organization might then be referred to as Type III problem-solving.

The name of a particular block in this study, would represent Type I, the concurrent classification of all the objects is Type II, and the logical reasons for reponses for the relationships are Type III. These kinds of distinctions will, hopefully, be useful in the future for more careful descriptions of cognitive behavior.

For purposes of this study, color, form, and size labels are taken to be less complex than observations regarding principles of relation, that is, the formal or logical relations existing when size, color, and form are to be considered concurrently.

Lack of literature on the latter is stressed by Karplus (1964) in the 1964 Piaget Conference. A considerable amount of literature is developing on the basic categorization process, on semantic generalization, on verbal mediation, and on reversal-shifts due to language control, but studies of concurrent categorization (the present study), and of formal (in the Piagian sense) systems is only beginning.

PART TWO: OBJECTIVES

Statement of Objectives

The three objectives of this study as originally stated were:

1. To describe the solution of a three-dimensional classification problem as affected by the developmental stages of students from the 1st through the 9th grades. (this is the principle objective)

2. To utilize the Bruner (1956) and the Inhelder-Piaget (1955) systems of describing stages of cognitive development as these stages are seen in responses to the task assigned.
3. To determine by multi-variate analysis if differences in developmental stages are related to verbal and/or performance aptitudes.
4. A supplemental objective is to test the effect of increasing the level of discrimination, using a sample of 10 subjects at each age level. Discrimination instructions involved calling attention to the various sizes, shapes, number of angles, and colors by directed questions such as: "Name some of the things you notice about this object." This is followed by specific questions on the critical variables if the student has not mentioned them himself.

As the study progressed, two additional objectives were added, as follows:

1. To evaluate the relationship of spatial performance as measured by the D.A.T., on ninth-grade students.
2. To ascertain the effect on adults of more explicit verbal instructions, with the aim of establishing some upper performance paramenters.

Emphasis and Experimental Trends

Because of the fact that this study was small contract, and somewhat limited in scope, it was necessary when procedural decisions were made, to favor the major objective, which was: to describe developmental stages, in the span of grades 1-9, as the subjects attempted to sort and place the blocks in this experiment.

There are some useful parallels between the Bruner and Piaget systems which makes it possible to use them in a co-ordinated fashion to describe some behavior. For example, Bruner's description of "focusing" strategy is somewhat comparable to the "centering" process as described by Piaget. In both, the subject is concerned with a particular concrete aspect of a stimulus field, and finds it rather difficult to shift. In Piagian terms, "decentering" is evidence of developmental maturity. In this study, objective one is thus discussed in terms of objective two.

Piaget describes the shift from a concrete stage to a more formal stage in which the person becomes more able to use verbal systems independently from the particular stimuli. This reasoning factor was considered to be a basic one in the study, and so both verbal, and non-verbal measures of reasoning were utilized. Although "non-verbal" is often taken to be a "performance" variable, the area of "performance" is a wide one. In the orginal budget discussion, the CTMM short form was proposed and accepted. This test gives a language and a non-language or performance score. In this case, non-language is a particular kind of performance variable (Anastasi, 1958) which includes reasoning about making change, memory, and perceptual discrimination.

Since a spatial factor is not included in the shortened factored series of the CTMM, the spatial section of the DAT was added for 9th graders to give some estimate of this kind of performance also.

Limitations and Extensions

The description of developmental trends, the major objective, will be reported in detail, as the major contribution of the study. The kind of strategy used and the concrete-formal aspects must largely be inferred, since these subjects, as with Hull's (1920) are very limited in their ability to explain why they perform the way they do. We may make some rather direct inferences on focusing, for example, since the scoring will show exactly which factor was being used most.

Since some significant differences occurred between grade levels in language and non-language IQ's, covariance-analysis was used in the comparison of grade level trends in the basic matrix-sorting problem. Additional groups were added at 9th and adult levels to observe some upper performance limits.

PART THREE: RELATED RESEARCH

The research reported here is rather extensive in coverage because in this relatively new field of cognitive behavior, a variety of factors must be taken into account in interpreting research in the area. As with more established fields, segments of this total field will undoubtedly be broken off in the future for more intense study. Still, some effort to maintain perspective and general orientation is required, even for an informed observer. The first section has to do with experimental approaches, and the second outlines related variables. The third gives information on the "stage" theory of development. All the variables listed have been demonstrated to have an effect on cognitive behavior. They cannot be disregarded. The implication is also that no simple dimension of cognition is likely to provide a simple theoretical basis for interpreting results.

EXPERIMENTAL METHODS OF STUDYING COGNITION

There are two general approaches in the study of cognition or thought, experimental and developmental. The latter is best exemplified by Piaget, in which age is taken as the basic variable. Experimental work is of considerable variety, but the variety is contained in only a few procedural categories. Most of the variations are based on kinds of stimulus control. Even when receoption strategies are allowed, the checking procedure is usually immediate. Of the several types , the pre-set attribute approach is most common.

Categorization Based on Experimenter-determined, Pre-set Attributes.

In these cases, the experimenter decides which of one or several attributes will define a category. The subject is then checked on each attempt, until he discovers what dimensions are relevant. Varieties within this type include: (A) Subject does not know what he is really being scored for doing, and (B) Subject is informed he is looking for certain attributes.

Examples include the abstract forms of the Hanfmann-Kasanin test (1942), the objects of the Goldstein-Scheerer test (1941), the Goss (1958) adaptations of the block-sorting test using nonsense syllables, the content dimensions of cards in the Bruner, et al (1956) A Study of Thinking, and the eight element choice patterns used in the Glanzer, Huttenlocker and Clark study (1963), which were designed to standardize the Bruner approach.

In all of the studies above, the experimenter decides on the dimension which defines the concept such as a "blue cross with a wavy background", and observes how many choices it takes for a subject to figure out the concept. This is somewhat different than Hull's original approach, in that for Hull the subject was unaware of the intent.

This somewhat artificial approach does allow the careful regulation of the amount, kind, order, and frequency of presentation. Some experimenters (Bourne and Haygood, 1961) have studied the effects of redundant information, and others the effects of positive versus negative instances (Archor, Bourne, and Brown, 1955). The latter has been particularly productive in analyzing disjunctive as compared to conjunctive categories (Bruner, 1956).

Grouping and Abstracting

In these experiments, the subjects are asked to "put things together which form a group" (Bruner and Olver, 1963) or "in what ways are x and y alike?" The latter type is often used in intelligence tests where the subject is asked to specify why selected things or classes are alike or different.

Related to the above are vocabulary tests which in essence are "concept" tests in that they require a definition of a particular class of objects or actions (Church, 1961, p. 172). Similar to basic vocabulary tests are analogies and metaphor tests (Empson, 1951), proverb tests (Buhler, 1951), and the word context test of Werner and Kaplan (1965).

Eleanor Gibson (1951) amended Hull's (1921) "stimulus discrimination theory" of concept learning, which emphasised a molecular approach. A general criticism of the molecular approach, involving the study of lists and rather specific associations, is that it is restrictive when broader problems of meaning and organization in human learning are to be considered.

Welch (1940) found that children are less able to learn higher order concepts ("animal" in such as the animal--cat--siamese series). He postulated that such abstractions are further from a direct "stimulus" trace. Brown (1958) suggests that frequency of common use is the explanation in such cases. Another qualification is in the work of Kendler and Vineberg (1954) who found that naming discriminable parts of a problem to be presented later facilitated concept learning. Both relevances and naming procedures were found as variables by Archer (1962). Both men and women did better when the relevant material was obvious, but men did better on a task where they were more familiar with the label of a part. The facilitating effect of organizational structure on memory was noted by Schwartz and Lippmann (1962). It appears then that both discrimination of essential parts and their associational relation to each other are factors in concept learning.

Kuo (1923) studied the general process of induction. Smoke (1932, 1935) gave "grouping" as the essential element in concept formation. This general procedure was demonstrated by Heidbreder (1946) in her work on perceptual grouping and concept formation. She used patterns of various numbers of similar figures and designs of both a concrete and abstract nature. Baum (1954) and Deterline (1957) have criticized her conclusions that concrete elements are learned easier by suggesting that variations in the stimuli are more critical than "degree of abstractness."

Reed (1946, 1950) conducted a series of experiments where subjects learned nonsense syllables as labels for a specific word embedded in word lists. Forty-two sets were presented in pairs so that the subject could scan for common stimuli.

Buss (1950, 1956) completed a series of attempts to relate concept learning to "shifts" in discrimination based on mediational (grouping) processes. This position has been supported by Harrow and Friedman (1958) who studied "sets" on the Wisconsin Card Sorting Task. That verbal mediation processes influence the formation of concepts is seen in Goss (1961) and Kendler & Kendler (1962).

Ausubel (1963) has developed the subsumption process theory which is based on hierarchal cognitive structuring. Similar work is seen in Bruner (1956), and Hunt (1962). The use of words in problem solving was found to be ~~advantageous~~ of advantage by Kendler (1960).

Developmental Implications

Of course, these experimental approaches may be related to developmental stages by comparing the performance of various age levels. Piaget's work in general has been largely descriptive, in which the increasing ability of the person to extend cognitive skills is illustrated with a variety of tasks, (Flavell, 1963). In the present study, a combination of the above will be used, in that an ideal, pre-set solution is available, but the subject is put entirely on his own in attaining it in his own degree of success.

FACTORS INFLUENCING CATEGORY DEVELOPMENT

In this section, a brief review of some basic factors involved in category or concept learning will be given.

Positive and Negative Instances.

Hovland and Weiss (1953) study of communication and concept learning gave detailed attention to positive and negative instances. Hovland (1952) used a 2 x 2 x 2 and a 3 x 3 x 3 matrix but only for the convenience of the experimenter in cataloging instances of size, shade, and shape. Glanzer, Huttenlocker, and Clark (1963) extended and refined the Hovland study by suggesting that the effects were varied in terms of the subjects considering attributes of the stimulus, rather than more general hypothesizing. "Synchrony" in sequence was discovered as a variable by Delambel and Stolurow (1956).

Cognitive Load.

As the subjects in the present study looked at 54 separate objects in a variety of colors, sizes and shapes, a relatively "high" degree of load was assumed. Archer (1954) has demonstrated the effect of load on identifying visual patterns. Bruner (1956) refers to "cognitive" strain as being varied with different strategies. Miller (1956) indicates that there are limits to the human ability to "recode" information, which are affected by "chunking."

Labeling and Discrimination.

The extreme sensitiveness to control by language of the human makes awareness of this factor critical to the present research. Corey and Goss (1956) described the role of verbal labeling in the block-sorting behavior of children. A similar finding was reported for problem-solving by Gagne and Smith (1962).

Instruction, Set, and Transfer.

Ewert and Lambert (1932) found that language symbols reduced manipulatory moves necessary to solve certain problems. Using pre-set combinations of color and form, Collantine and Warren (1955) found that multiple problems in training facilitated transfer and provided a more generalized solution-base. Noble, Alcock and Frye (1959) found that lack in instruction severely retarded early learning in a discrimination task.

Rothkopf and Coke (1964) used prose as a more natural source for data or set, and questioned whether simultaneous presentation is as effective as the anticipation method in verbal association.

The theoretical positions of Osgood, Skinner, Ausubel, Bruner, Hull, and Estes were reviewed by Silberman and Coulson (1964) in a U. S. Office of Education project which demonstrated that performance on teaching machine programs is based on the "gap principle", the "irrelevancies principle", and the "mastery principle." Stolurow (1963) in a series of U. S. Office projects has also emphasized the importance of cue instruction on transfer. Both of these reflect the variable of degree of experience.

As will be seen in procedure, the fact that learning is such a vital part of mastery, in addition to maturation, means that the instructions to subjects must be carefully considered and controlled in a study such as the present one.

Motivation and Reinforcement.

So many studies are available here that only two examples are given as illustrations. Such variables are related to experimental techniques of rapport, "reward," and confirmation. Curry (1960) found for color and number sorting that the most effective reinforcement was dependent upon the amount of other confirmatory information available. Hull's K factor (magnitude of reinforcement) was studied by Prince (1965) who discovered that it was related to the generalization gradient. Implications for this study include future variations in which increased K might cause a regression to lower performance levels in the present task of complex sorting.

Individual Disposition and Cognitive Style.

We should expect individual differences to be observable in sorting behavior, since a most pervasive attribute of humans is individuality. Wilson, Guilford, and Christensen (1953) define originality in terms of cleverness. In concept learning problems with pre-set solutions there is no premium for such variation; in fact, scoring must quantitatively take these into account. The Fritsky and Messick paper (1962) noted that analytic, rather than relational categorization was increasingly preferred with immaturity. This finding was based on increasing ability to discriminate an embedded figure. Children in grades 1-4 go through three processes in problem solving (Kagen, _et al_., 1964) including "the initial categorizing of information," storage of the encoded information," and (transformations and mediational elaboration of the stored material). But these investigators maintain that the analytic tendency increases with age, and shows marked individual differences. They report work with a conceptual style test (CST) in which 4th grades gave 4 analytic as compared to 9-10 for sixth grades. Lichtenstein's (1964) work on cognitive control measured tolerance for unrealistic experience and flexible-constricted control. Gardner, et al (1959) review the extensive effect of perceptual and cognitive organization as factors in cognitive control.

Reasoning, Thinking, and Problem-Solving.

Taba's (1964) report of a Cooperative Research Project, reviews the work of Bruner and Piaget as it applies to teaching strategy. She illustrates the fact that instructions can raise the level of problem-solving behavior. A variety of factors influencing thinking is described in a review by Vinake (1962) in which motivational and situational variables are stressed. The influence of past experience on reasoning was demonstrated by Sagstad and Racheim (1960) to involve much more than perception.

Stimulation of cognitive processes is receiving much attention as illustrated in Green's (1963) direction of a series of processing problems in an institute held at Rand corporation. They included memory processes, language processes, pattern recognition, problem-solving, and others.

Attention and Stimulus Selection.

Often neglected or assumed as obvious is the initial selection of response-guiding cases by the subject. The simple device of placing a dot over relevant stimuli was found effected by Simon (1962). Rosenberg and Cogen (1964) in a word association problem stress the selection of referent and non-referent stimuli, on which the speaker, by "sampling" and "comparison" sets up a referent for identification by the listener who may respond by object, concept, or speed sets. Such factors were found to be significant in the present study.

Stimulus Generalization.

This is related to the problem of finding borders for categories. In conditioning it refers to assumptions by the subject that stimuli are equivalent (Maier, 1945). In our block sorting experiment, this is a vital consideration, since each layer has adequate and inadequate equivalents.

In the present experiment, the subject illustrates this process when he identifies a particular form for example, despite variations in size or color. Mandler and Cowan (1962) point out quasi-logical generalization judgments which involve transitivity and symmetry. Jenkins (1960) suggests that generalization of meaning might be related to the polarization of terms used. This would imply that inability to label a form for example would increase the generalization response to include similar forms.

Assimilation and Accommodation.

According to Beach (1964), if the person has an existing category structure to utilize, he will recognize the familiar, assimilate the related, and be able to identify the unfamiliar. These inference processes are similar to Piaget's (1958) use of the terms, except that Piaget assumes developmental pressure to accommodate to the new by developing additional "schemata." Beach's work stems from Brunswik's (1956) theory of probablistic functionalism. The implication is that the subject can only partially relate sensory input to perceptual--cognitive structure. The resultant behavior is veridical (Bruner, 1957) to the degree of correspondence. How this process operates under varied conditions of information presentation is discussed by Secrist and Wallace (1962). Revision procedures based on past instances as used by humans and computers are given by Denton (1965).

Task Variables.

The S-R, cognition controversy has clearly illustrated the task-variable problem. One solution, now being attempted in some experiments is to apply both approaches to the same problem. There is some indication, however that these explanations are not mutually exclusive, but may be able to different kinds and levels of problems. The change, possibly, may come at the transition period between what Piaget calls "concrete" and "formal" operations, at least in terms of the criterion of most generally useful.

The problem here has been in the establishment of standardized procedures and evaluative measures for experimental work, because generalizations fitting one task do not necessarily apply to another. For example, in the Glanzer, Hutenlocker, Clark study (1963) the principles developed refer to the pre-set stimuli problems of the type used by Cofer and Bruner which in this case involved variations among six variables.

In a study on concept attainment in children (Johnson and O'Reilly, 1954), the children were asked to identify birds of varied characteristics. Verbal phases speeded the process. Gradients and categories were studied by Wallach (1959). Another concept attainment study showed the influence of overlapping sub-categories. (Wallach, 1962).

Another kind of task described by Johnson (1964) seems to require another model. In this case there are five channels with either + or - values. This gives 25 or 32 different patterns. The experimenter in advance decides which principle is to be correct in a given trial-set which will divide the patterns into two groups. Varieties of problems, based on series, sequence, etc., could be used. Johnson describes scanning and complex strategies.

Conjunctive and Disjunctive Concepts.

Where one concept such as "animal" subsumes a series of others for example, "dog" and "cat" it may be referred to as disjunctive; that is, an unknown sub-class may be an "animal" in many ways. However, "animal" as compared to "vegetable" or "mineral" is conjunctive in that the conditions for entry may be particular at that level. This shifting of definition has caused some problems (Earl Hunt, p. 167, 1962).

In the block-sorting problem of the present study each block has a correct place in a particular section of the matrix. In this sense the task is conjunctive. At the same time, a particular form, say a cube, occurs in different colors and sizes. The class of cubes, then has irrelevant disjunctive sub-elements.

Another way of expressing this problem is in Inhelder and Piaget (1958) who has noted the logical differences in p "and" q versus p "or" q or "both", as elements in advanced cognition.

Memory and Storage.

How much learning represents a "monadic" unfolding is a question. Piaget has emphasized that he is studying "natural" development, but some critics feel he has in some cases ignored cultural influences on cognition. Glucksberg and Laughery (1965) have demonstrated that incremental and sequential learning utilize different operations: perceiving, scanning, concept incrementing, and rehearsing. Where classes are ambiguous (Feldman, 1963) probabilistic hierarchies develop.

It should be apparent in a study like the present one involving 54 objects, that if storage load is a variable, this task is harder than one with fewer items, unless some organizational principle is possible. Miller (1956) suggested that "chunking" could reduce load. This was followed up by a study in which Lindley (1963) demonstrated that coding cue effects were related to meaning fulness. Earl Hunt (1961) pointed out that in concept learning the subject tries to "find a rule to assign any instance in the universe to any appropriate class," and that the serial position of instances was critical in concept development.

Memory (Mathews, 1954) is related to the number of classification categories. It could perhaps also be inferred that performance could also thus be affected. Bartlett's reconstruction theory (Olfield, 1954) stresses the reconstruction aspect of memory. Both form and input load affect this process (Denny and Gamlin, 1965). Input as the result of search may not be directly need related (Driscoll and Lorzetta, 1965).

Linguistic Structure, Mediation, and Levels of Abstraction.

Johnson's (1962) article on linguistic structure on concept formation contends that abstract concepts are to be found later than concrete concepts, but that cultural effects must be taken into account. Metaphorical elements in which a conflict between perceptual and cognitive reality are reviewed by Anderson (1964). An interesting aspect of this problem is seen in the relation of sonic vehicles for meaning discussed by Langer and Rosenberg (1963). They review experiments with spatial, color, directional and evaluative referents in which the subjects related sound patterns to verbal descriptions.

When a subject is confronted with an array of objects, he abstracts elements of the situation for consideration. While abstraction was considered as early as 1916 (Fisher, 1916), it is still a relatively obscure process as defined in the literature. English (1922) and Colby and Robertson (1949) contributed to its definition. The monumental work done by Heidbreder (1946), and reviewed by Dattman and Israel (1951) raised the issue of what kind of concepts were easier to learn, concrete or abstract.

The function of abstracting as part of mediation in problem-solving is described by Fenn and Goss (1956), by Cofer (1957), by Mednick and Freedman (1960), and by Jeffrey and Kluppel (1962).

What is of particular interest here is whether the abstract concepts of form, color, and size have developmental variations.

Recent work by Pollis (1964) indicates an underlying associative structure with variations in abstraction level, were found to produce significantly different responses in 2nd and 3rd grade children by Wittrock (1965). The use of an object sorting test was used by Willner and Reitz (1965) to explore the term "associative neighborhood" which involves meaning clusters.

STUDIES RELATED TO THE DESCRIPTION OF DEVELOPMENTAL STAGES IN GROWTH

General growth curves for children are well described by Jersild (1954) and Carmichael (1954). Yet, the area of cognitive development is still poorly described. Here, the systems of Piaget and Bruner will be described, and then some examples of related research will be reviewed.

The Developmental System of Jean Piaget.

Piaget's system of cognitive development has been carefully described in J. Mc V. Hunt (1961) and in Flavell (1963). In the course of many years, Piaget used somewhat different notation systems but it is possible to arrange them in workable order first in terms of three major divisions, as is sometimes seen, with sub-periods called stages. The first period is the sensory-motor, the second is the concrete, and the third is the formal. The concrete may be further divided into three periods, the preconceptual, the intuitive, and the the concrete operational, giving five basic periods. Or, the concrete may be divided into pre-operational and concrete operational.

As was done in the Bridge's (1932) study of emotional development and in the Erickson (1950) and Maslow (1943) systems of personality development, the order of cognitive development seems best described in stages, rather than as specific characteristics of a given age level.

It is important to note that periods of development which involve "decentering" and "re-ordering", involve both perceptual and cognitive aspects. Both assimilation and accommodation of new experience occurs. This is to say that a labeling system may be concrete or abstract in reference to the same solution. In other words students may solve a problem so that it is perceptually similar, but may have different "cognitive" maps for doing so.

It should be noted that when a "schemata" is first developed, that it constitutes the basis of readiness for assimilation and accommodation for new experience.

Since reference will be made to Piaget's periods and stages of development, we will review here the basic framework of this developmental progression for reference in the analysis. Since there are some minor variations in labels of the periods in different reviews (Flavell, 1963) we will define the terms as they are to be used here.

(1) The Sensory-Motor Period. Many ready-made schemata are present in the newborn infant as reflexive schemata (sucking, looking at lights, simple vocalizing). These invariant functions are modified with maturity and experience in the sense that they become part of larger behavioral actions. Some object permanence is seen. Spatial awareness develops in that a child will try to remove an obstacle.

There is some symbolic imitation and an increasing capacity for detours develops.

We would expect that these early responses would have been assimilated into more complex responses by the time we begin to look at them in this study at the first grade level. It would be rare that the sheer physical action required would be a variable of consequence in responses studied here.

Werner and Kaplan (1963) emphasized the importance "pointing" as part of this developmental period related to spatial awareness. In each of these stages early behavioral forms are incorporated and coordinated into the new.

(2) The Pre-Conceptual Period. (sometimes called Stage I) The best definition of this period is simply to say that it grows out of the sensory motor period and preceeds the concrete period. Mental imagery is here taken to be a form of representation of "world of sensation". This imagery is considered by Piaget to be implicite response, not simply a passive storage.

The "whats-that" question appears, referring both to name and its placement among things (J. M. Hunt, 1961, p.187). He is gradually lead toward agreed upon relations between referrence and names. Reasoning (Piaget, 1945, p. 237) is without reversible nestings of a hierarchy of classes and relations. Transduction is seen at this time, which is a form of reasoning which preceeds from the particular to the particular. Assimilation is direct and distorting because it is centered on individual elements which happens to interest the subject. (J. M. Hunt, 1961).

Categories and variables come into being then as learning sets which generalize the individual objects and relationships.

Children cannot separate a cardboard square from a circle in the early stages. Seriation is seen in the ability to order lines. They can put sticks against the edge of the table, but cannot form them into a line on a general surface. J. M. Hunt (1961, p. 197) says "representation appears when new objects and events are assimilated not merely by schemata which are activated by perceptible similarity but also to those people by signifiers. The connection between signifers and signified is by images and some cognitive representation." At this level, true generality and object constancy are missing. Hunt points out that in imitation accommodation is predominant, and that in play assimilation is predominant.

(3) Intuitive (Stage II, ages 4-7) Piaget has stated that classifying derives from the action of grouping objects together according to aspect in which they are preceived to be similar.

In this period numbers arise from classifying and ordering (Piaget and Szemenska, 1941). Thought is in dis-equalibrium, but stablizes in Gestalt like "groupements." Some combinativity or transitivity is seen (Hunt, 1961, p. 201) in that the child recognizes the word "children" to include "boys" and "girls".

In II 2A they cannot conserve liquid but in IIB, they can do some double seriation with dolls and sticks (J. M. Hunt, 1961 p. 213). "Conservation" is used as a term by Piaget to describe the ability to keep a standard amount in mind despite its appearance in different forms. Some evidence appears for the ability to "decenter" and to become aware of a class as represented by an individual case.

(4) Concrete Operational (Stage III, 7-11) In this period, the person moves readily from part to whole. A series may be visualized from either end. This is called reversibility. Classes, relations and numbers are emerging in usable forms. A mobile equilibrium appears in which successive actions can be combined into what he calls "transitive combinativity."

While at about 4 years spatial orientation is largely global, at 3A about 7 the child is able to take edges more into account (Piaget and Inhelder, 1948).

The order of development regarding material appears to be quantity, weight, then volume. Children (III3) can conserve quantity but not weight. By nine to ten they can order weight serially.

(5) Formal (IV. Beginning at age 11-12) In this period the person may use logical propositions to understand a law he can decenter and use reversibility. The central processes come to dominate over perception. They are concerned not only what is, but what might be (J. M. Hunt, 1961, p. 225).

During this time cognitive behavior may be studied in terms of the sixteen binary propositions of two valued logic (J. M. Hunt, 1961, p. 231). They may be grouped into INRC operations. The I is the recognition of identity, the N is the negation or inverse. R is for propositions which reciprocally balance each other, and C is the correlate of N and R. (Note that in some accounts, Roman I is sensory motor, II is concrete, and III is formal) In his visit to the United States (1964), Piaget refers to four periods: (1) sensory motor, (2) pre-operational, (3) the concrete operational, and (4) the formal.

J. M. Hunt (1961, p. 168) points out: "In the second stage which occurs usually roughly from two to six or seven. The child can perform certain set theoretical operations. He can now respond to the intersection of two classes as a class, and can note that classes are included within classes. However, the idea of subtraction of sets as not yet occurred, which suggests that strategies which make use of information from negative instances cannot be developed. In the third stage, which is well established by age 8, subtraction of sets comes within the child's capability. Somewhat later, in second sub-stage of the idea of union of sets occurs. Only at this time is true disjunctive concept learning capability formed."

Space concepts seen in topological relationships which occur first. This involves proximity, separation, order, enclosure and continuity-discontinuity. This is not primitive perceptual awareness, but is gained by experience. Later development is seen in awareness of projective space which includes object localization in relation to perspective or coordinate axes. These are followed by Euclidian space studies by Piaget having to do particularly with conservation of length, area, and volume. (Piaget and Inhelder, 1948)

Some representative studies. Some studies which have attempted to verify Piaget's developmental periods include an early study (1931) by Johnson and Josey who reported that children are capable of logical thought at least a year sooner and Piaget (1923) had reported. Huang (1943) also found discrepancies in norms for concepts of physical causality. Carpenter (1955) began some pilot work following the Piaget (1936) book on the origins of intelligence in children. Children show variations in kinship terms (Danziger, 1957). Braine (1959) found children able to refer to position order two years before Piaget noted it, but did observe emerging stages. B. W. Estes (1956) did not find the patterns in numerical and logical thinking that Piaget did. The work of Piaget and Inhelder (1948-1956) on space as published in English prefaced a later work on geometry. (1948-1960) The first is the date in French, the second in English.

In the latter, particular care is taken to try to avoid making any use of a knowledge acquired in formal education. The childs growing ability to be able to respond to distance, length, angles, area, volume, and locating a point in space as described.

In Piaget's work on geometry (1960, p. 359) he notes that children at stage IIIB around ages 8-9, "Can measure correctly, using cubes as units but they still cannot carry out mathematical multiplication, which means they cannot establish numerical relations between lengths or areas, or volumes." He also notes that equality of volumes of different dimensions is seen in stage IV (formal operations); "...they start from the limiting lines of a figure and only later do they calculate the space contained within the lines." (Piaget, 1960 p. 395).

"...at stage IIIB when measurement first becomes possible in one or more dimensions. Children are also beginning to use natural horizontal and vertical preferrences in order to construct comprehensive systems of spatial relations..." (Piaget 1960, p. 404)

"If a child can transfer a given length from one straight line to another. He can also transfer it from two straight lines to two or more, or from three straight lines to three or more." (Piaget, 1960, p. 153)

Piaget's method of having the student locate a point in two dimensions is to have the subject reproduce a point from a given model to a blank sheet. During stage I to IIB, the procedure is essentially simple visual. During stage IIB, the subjects begin to measure, and during stage III, the need for two measurements instead of the use of oblique angle referrence is achieved. But no difference is seen in two dimensional and three dimensional point location;

> "but as between two dimensional and three dimensional measurement there is no time lag whatsoever. The reason must surely be that one dimensional measurement is synthesis of additive logical groupings (sub-divisions and change of position) while measurement in two or three dimensions depends on multiplicative logical groupings (subdivision together with order-of position in two or three different directions). Hence once a child has mastered the grouping such multiplicative spacial relations he can coordinate three series as easily as two. However, it should be stressed that psychological equivalence of two and three dimensional measurement derives from the fact of grouping." (Piaget, 1960, p. 170)

We should note that locating a point in space maybe less complicated than responding to color, size and form, as in the spatial relationships of the present study.

When studying reciprocity as a justice principle, Deulsin (1959) found a reversal of Piaget trends with age. Developmental differences between second and third graders in awareness of control factors in an experiment was noted by Ervin (1960a). She also used inclined plane, truck experiment (1960b) in which she found it difficult to eliminate the effects of prior training. Elkind (1961,a,b) replicated some of Piagets work on conservation in quantative thinking and in general substantiated his age-related stages. Elkind's findings on volume places conservation at a later age, 15, than Piaget, but the order of quantity, weight and volume is held.

Flavell (1963, p. 379-404) discusses the general tone of validation studies in which he notes that the general sequence of periods has been supported while specific age norms are not as fixed as Piaget may have implied. He notes that tasks variables have been particularly hard to control.

The Bruner System

Bruner's article (1959) on perceptual readiness explained in detail how categorizing behavior takes the person beyond the sensory data given. In this Bruner outlines how cognitive transformation is the process of using criterial attributes in defining a class of equivalent stimuli in the course of cognitive growth. Bruner describes the development of human intellectual functioning as a series of technological advances in the use of the mind.

Bruner says that ratiocinative amplifiers are made available by the culture largely in terms of language. The inborn unfolding theory is rejected by Bruner. He maintains that growth depends on techniques and experience. Of course, a sufficiently complex nervous system must be assumed. Representation systems then become mediators between the person and his environment. The quality of his response depends then on the quality of the system.

Bruner's analysis is based on language development, particularly between ages 4-12. The two systems, Bruner's and Piaget, are not quite parallel, but some stages have semi-equivalent terms. For example, Bruner's "enactive representation" is similar to Piaget's "sensory motor." Bruner's "ikonic" is a more concrete period, paralleling Piaget. Bruner takes the position that language not only represents but actionally transforms experience.

By age 7, matrix transformation behavior is achieved. (Bruner, 1964) The students reproduce a 3 X 3 two dimensional matrix involving three varities of height and three of diameter. In the experimant the reproduction is then reversed to see if they can accomplish this in backward order. A higher order response is necessary. Bruner also observes a more accurate dimensional language developing between 5 and 7.

Lack of conservation in liquids where four year olds think that the same amount of liquid poured into a larger container is more, is achieved more easily by 5-7 year olds especially when some internalize verbal formula keeps the concrete perceptual data from being overwhelming.

The kind of language is related to the type of grouping strategy. The three levels given by Bruner (1964) are: heaps, complexes, and super-ordinates. Heaps are arbitary groups; in complexes groups are based on some rule which does not accept all member uniformly; superordinate structures, such as "animal," are more generally abstract and inclusive. In these, appropriate functional attributes begin to predominate over perceptual in 7-8 age year range. Perceptual features such as color, form and size appear earlier than the functional group, such as, "you can wear them." When allowed to group pictures to as many as were desired (Bruner, 1964) 61% of the six year olds chose pairs, but only 25% of the eleven year olds chose pairs.

Bruner points out that a hierarchal structure of rules is also developing in which levels of abstraction need not be opposed, but become interlocking. This is a feature which Piaget refers to as lattice structure.

Older children are able (Bruner, 1964) to "recognize visual displays in manner governed by a dominating frame of reference that transcends momentary and isolated bits of information."

Representative Research on Developmental Stages

A summary of hypothesis regarding thought in 1955 (Johnson), shows little change from a similar current reviews. Perhaps the most striking new developments are in the extension of "layers of learning", and in the process of "category forming." Mott's (1939) three year study of abstract concept development stressed the importance of concrete experience. Sigel (1953) studied the ways children group familiar objects, and found a developmental sequence from perceptual to conceptual sorting. The Kendler's (1956) found evidence of inferential behavior in 3-4 year olds. Size transposition behavior in children 1½ to 3½ years old was studies by Rudel (1958) who found verbal behavior not yet a significant factor. Social status differences continue to appear (Siller, 1958). Ervine and Foster (1960) found that 22% of 6th grade boys confused the terms smaller, lighter, and stronger. Ross and Nissim (1960) found that grouping colored cards to help define certain polar terms was less complete for 4th graders as compared to college students. When the Hunter-Pascal concept formation test, which allows patterning, was used by Larsen (1959) the MA of 6th graders showed more relationship to learned success than CA.

A somewhat contradictory finding on functional responses was reported by Davidson and Longo (1960) who found that 10 year olds showed similarity in heterogeneity of response compared to adults with a decline in functional as compared to contiguity type association.

Earl Hunt (1961) studied the effect of presenting total instances defining a concept as compared to the greater effect of key instances. Kendler, Kendler, and Leonard (1962) found a 50% increase between the ages of 5 and 7 in the use of mediating responses. The importance of discrimination in perception was stressed by Suchman, Aschner, and McCue (1961) who found increasing conceptual clustering with age. Russel and Saadeh (1962) report the use of a test involving a difference between functional and abstract terms. Wohlwill (1963) compared students ability to respond to perceptual abstract and symbol stimuli. Under the abstract condition the criterial dimension of number had to be abstracted from color, form and position which were irrelevant. The use of the numeral itself (symbolic) showed a cross-over at age ten in favor of the absolute over relational. Despite the availibity of verbal or symbolic mediator subjects preferred a relational response. The set to chose the smaller or larger of a given pair thus seems rather strong when a new pair is presented.

Classification in primitive society is reviewed by Price-Williams (1962) he found the ability of children 6½ to 11 years of age to be rather similar for Bush and school children using familiar material.

Fowler (1962) feels that the cognitive ability of children has been underestimated, and that research has been focused on too simple perceptual problems. Yudin and Cates (1963) found that 14-16 year-olds showed consistently more ideal strategies than did 12 year-old subjects. Weir's (1964) study, using ages 3 to 20, showed that reinforcement had little effect on the strategy of younger subject and that 7-10 year olds tryed a variety of patterns despite differential reinforcement schedules. Adults showed less shifting.

Studies related to hierarchal, varied-dimensional, and matrix-type sorting.

Thompson (1941) used the Color-Form Test in which subjects sorted 12 cardboard figures based on form and color. She found distinct age differences in the 6 to 8 year olds as compared to 9 and 11 year olds. She noted that children first take color into account, then form. Reichard, Schneider, and Rapaport (1944) noted that 7-8 year olds could shift from color to form for a basis of grouping in the Color-Form Test. These subjects chose form over color at every age from 4 to 14. The highest incidence for color was age 6 at 42%. At age 4 only 10% chose color and 70% chose form.

Forgus and Fowler (1957) used a series of cards with various forms and colors. When familiar experiences were eliminated, forms then colors were preferred by college students. Duncan's (1959) review of problem solving noted that dominate response tendencies can have powerful effect on problem solving. The use of verbal anchors was investigated by B. J. White (1960) who found additional concepts hardest to incorporate furthest from the anchor. A method for hierarchal arrangement of descriptive elements is described by McQuitty (1960). Hazel and Bourdon (1960) have observed qualitative differences in sorting procedures, depending on the nature of the material. They raise the question of task complexity as directly related to sorting.

Using a series of letters and geometric shapes which varied in size, color, and material, Lovell, Mitchell and Everett (1962) reported on the "multiplication of asymmetrical transitive relations". Their test No. 4 involved leaves of graduated sizes and colors. The interaction of size and color is similar set union problems seen in modern math. They found age-related variance.

Rivoire, (1962) found that children developed topological concepts later than suggested by Piaget and Inhelder. Projective and affine relations were developed by six. A few four year olds had Euclidean concepts of space, but many fourteen year olds did not; no sex differences were observed.

One problem involved in concept learning has to do with multiplicative process. Is complex learning simply a combination of lesser parts and is logical multiplication simply addition of parts? Estes (1960) says that the process may be more complex than this. Trobasso (1964) says that binary sub-stages maybe added simply, but finds evidence of sudden solution when the subjects begin to attend two relavent dimensions. In studying component learning in a four-category concept problem, Trobasso found single cue sub-problems. The subjects were given geometric figures which varied in color, size, and shape and in two positions on the stimulus card. In each presentation the subject tried to anticipate the correct classification and then was told if he was correct after his response. This experiment is in contrast to the developmental approach used in the present study, since it involves immediate confirmation or disconfirmation of a trial.

When only two choices were presented Roseham (1965) noted that subjects attempted varied strategies on their own. When instructions were explicit and positively reinforced, a double alternation pattern appeared (spontaneously) with little awareness. Spontaneous patterning is an unexplored area in these kinds of problems.

Some of this kind of responding was noted in subjects in the present experiment in that when they had used one color or more size for a series they simply turned to another with the idea of using them all up.

Weir (1964) found differences in the strategies used by older and younger children in problem solving. Stern and Keislar (1965) found that 3rd grade children could be taught problem solving strategy, but that a simple hypotheses testing procedure was most effective.

Theoretical Aspects of Developmental Stages

The fact that concepts serve as critical points of contact between the individual and his environment is well illustrated in Harvey, Hunt, and Schroder (1961). Developmental stages in concept learning result from the interaction of maturation and environment. That these stages are somewhat invariant seems indicated, particularly, in the work of Piaget. J. McV. Hunt (1961) finds support for this general conclusion, but notes that the limits and type of content needs further definition.

The two basic perceptual processes in concept learning have been defined as discrimination, and generalization. It may be that "rules of transition are more important than a definition of a stage." (Rossin quoted in Flavel, 1963, p. 238).

Piaget proposes the term "grouping" or "groupments" for the organized elements of thought and the related operations bearing on these elements (Flavel, 1963, p. 172). The term "lattice" refers to heirarchel arrangement of the elements such that that subsumption levels are set up with a least upper bound and a greatest lower bound (Flavel, 1963, p. 172). Piaget gives these in nine logical groupings in the structure of concrete operations. Three are of particular interest here. Bi-univocal multiplication involves a two-dimensional cross-cataloging of two frames of referrence, for example, color and size. Co-univocal multiplication generates a triangular matrix (Flavel, 1963, p. 177-179). Bi-univocal multiplication gives a two-dimensional matrix involving two series, such as volume on one dimension, and weight on another.

(Flavel, 1963, p. 184-194).

Three dimensional structural considerations are not treated by Piaget, except for locating a point in space discussed earlier in this paper. Piaget and Inhelder emphasized that "collection of elements have structures as wholes." (1958, p. 270)

According to Piaget, the period of concrete operations includes preconceptual, intuitive, and finally the mastery of multiplicative compensations in volume conservation at about ages 11 to 12 or 6th grade (Hunt, 1961, p. 228). Between ages 11 and 12 in ages 15 and 16, he achieves "decentering", "reversibility", and "combinatorial analyses" based on logical structures called "latices". J. M. Hunt (1961, p. 115) says of this period "the result is something analogous to the hierarchal arrangement of information processing."

During the preconceptual phase of the second period of concrete operation the child develops his imagery or symbolic function based on deferred immitation. Reasoning is transductive at this time and lacks "the reversable nestings of hierarchy of classes and relations" (Inhelder and Piaget, 1955-1958, p. 237).

Piaget and Inhelder (1948, 1956) observe that topological space which includes proximity of points and separation of objects by edges is prior to projective space, which involves locating a point in reference to two axes. Awareness of Euclidean space is achieved later and includes the conservation of lines, angles, curves and distance.

During the intuitive stage, II, (J. M. Hunt, 1961, p. 198) three fundamental operations begin. First, classification and second, relations, such as, longer than, and numbering. This is a period of disequilibrium. The child at stage IIA cannot conserve a liquid in different shaped containers. By the ninth year children have learned to copy squares, triangles and circles.

During the last third of the concrete period the child achieves a mobile equilibrium. They can arrange objects and counters in one to one correspondence. At stage IIIA they line up sticks by sighting, but not until later in IIIB at age nine to ten do children achieve complete relativity of perspective. Quantity is conserved at IIA, but weight not until IIIB. Volume conservation is as late as formal period IV.

Conservation of volume is based on a formal type of reasoning that requires proportionality involving three variables (Inhelder and Piaget, 1955).

Affinitive transformations in which angles and length may vary but parallels remain parallel are of added interest since a kind of movement is implied (Flavel, 1963, p. 332).

At around age nine (Piaget, Inhelder, and Seminska, 1948-1960) the child conserves "interior volume" but not "occupied volume". That is, in reconstructing a solid with a new base he can get equal units but is confused about how much the total displaces.

Lovell, et al (1962) found that a group of 14 to 15 year old mentally retarded children have the operational mobility of an average 7½ year old.

The child in pre-operational period, ages 2-4, cannot take into account two dimensions. He can, however, "pile together" mentally objects in a set and can classify. To use hierarchal organization the child "must be able to assertain that certain properties of objects are invariant in the face of certain changes" (Sigel, 1964, p. 220). Bolles (1937) and Sigel (1953) found that categorizing shifts from structural similarity to conceptual labels. Ling (1941) demonstrated that 6 month old infants could discriminate form. Munn and Steinburg (1931) found that 15 month infants could learn the difference between a cross and a square. Rice (1930) and Crudden (1941) found some object constancy at ages 5 and 6. Long's (1940) findings showed that children would show stimulus generalization from circles to ovals.

When each of three concepts, form, color, and size were presented to 4 year olds at three levels of stimulus complexity, (degrees of relevancy), the strategy of 4 year olds was less random (38%) than 8 year olds (57%), thus showing more preservation (Osler and Kofsky, 1964). These investigators stress load and strategy as basic factors. They conclude that children may be solving these problems as if they were learning rote tasks, without coding the stimuli into response categories. The Lunzer study (1960), substantiated Piaget's findings that "interior" volume (within walls quantity) of cubes was conserved earlier than the "occupied" volume. (amount displaced).

As with form, children can discriminate color early (Sigel, p. 230, 1964), and they can match colors before they can label them. Sigel (1964) reports the following:

(1) Descoudres (1914) found that children from 2-6 favor color, but that preference for form increased reqularly from preschool to adulthood.

(2) Brian and Goodenough (1929) found form preferred early, color at three, decreasing to six, when form is dominant again.

(3) Colby and Robertson (1942) found increasing preference for form from $3\frac{1}{2}$ to $9\frac{1}{2}$. They found no difficulty in children's simultaneous use of form, color and size as a basis of classifying before 5 years.

(4) Honkavaara (1958) found that preference for form or color may be due to personality differences. Form reactors were more to be female, practical, realistic and socially

conforming.

Sigel (1953) reports that when meaningful material is used, children tend to ignore color. Sigel (1964, p. 231) also notes that Piaget indicated that multiple abstractions do not occur in the period of concrete operations (ages 7-11).

Sigel (1964, p. 232) reports that size is less salient than either color or form for the very young child. He concludes that "the concept of relative size seems a difficult one to learn, even though form discriminations are possible early."

If this were accurate, we would expect six year olds to sort blocks best in terms of color, then form, then size. Of course, size recognition is one thing and relative size, another.

Jackson, Messick and Myers (1962) found a greater differential response to color for males than for females in an embedded figures task. An overlay technique allowed for the effect of spatial memory. Males were also superior on spatial orientation.

Summary

It is clear that apparent difference in research reports relating to color, size, and form, have to do with overgeneralization. If "color," "size," or "form," are taken as absolute terms then all sort of inconsistencies seem to appear.

For clarity, it must be recognized that representations of color in one experiment are usually not equivalent to those in another. In one experiment, we may have shades of a given color; in another, common colors; in another, various intensities; in another, varied context. Of course, similar variations in size and particularly in form are available.

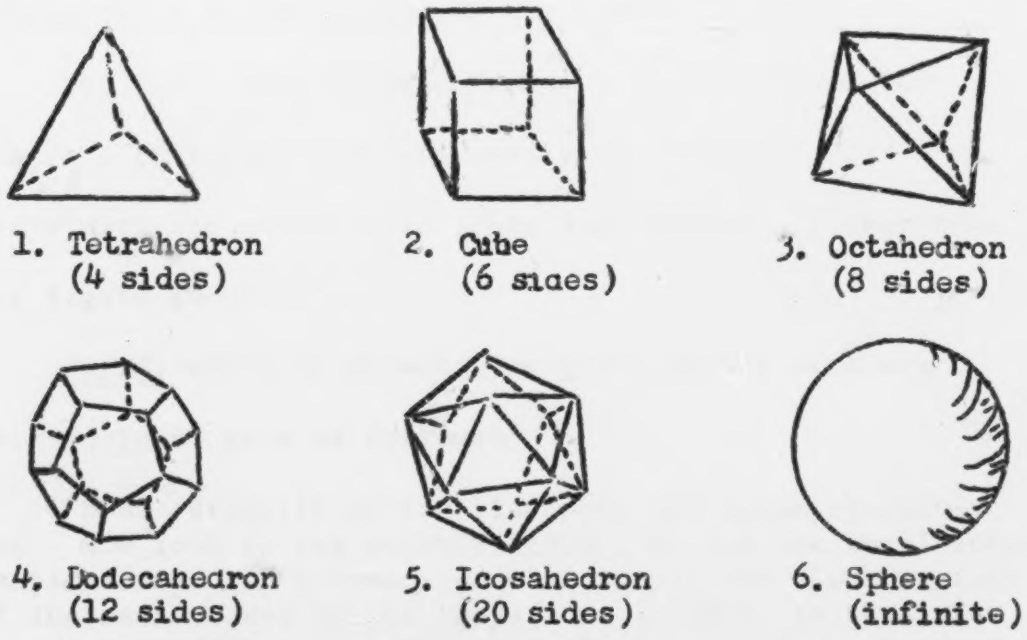
Thus generalizations about color, size, and form must be carefully stated in terms, not only of the context, but also the particular exemplars being used in any given experiment. To render these exemplars exactly equivalent in these three sensory dimensions (color, size, form) is not possible, and probably not desirable.

Thus, in experimental work involving these variables, it must simply be stated: "Under 'X' conditions, these results were obtained, with the conditions being carefully described."

Part Four: PROCEDURE

Material and Task

Subjects were *first* asked to look at a container with 54 objects in it. The objects were of *six* kinds, each made in *three sizes* (spheres were 1½, 1, and 3/4 inches in diameter with others in proportion) and *three colors* (black, yellow, white). Figure 4.1 gives the forms used:



1. Tetrahedron (4 sides)
2. Cube (6 sides)
3. Octahedron (8 sides)
4. Dodecahedron (12 sides)
5. Icosahedron (20 sides)
6. Sphere (infinite)

Figure 4.1 The six solid polyhed[illegible] used as stimulus objects.

Second, the subjects were asked to look at three movable trays near the object container box. The trays were pivoted as seen in Figure 4.2.

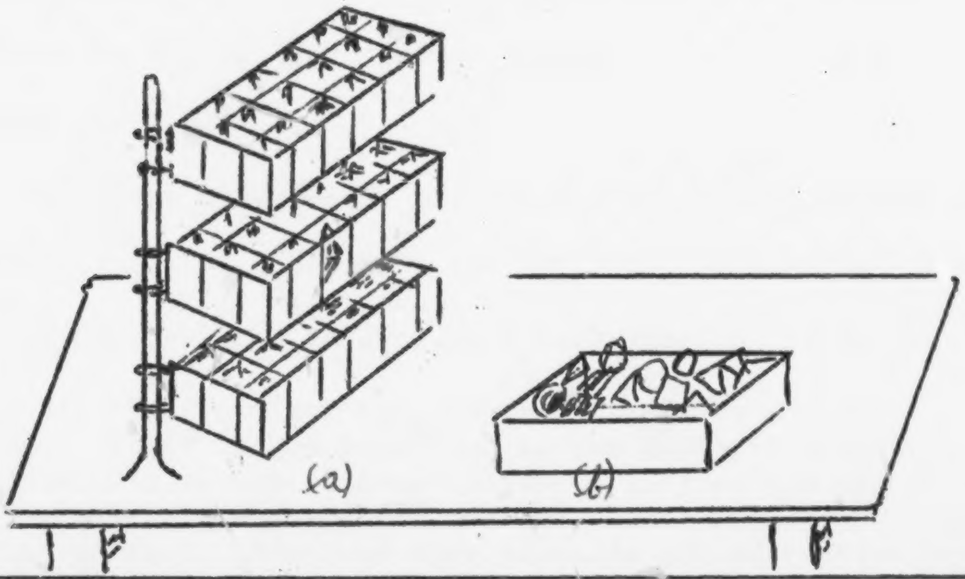


Figure 4.2 (a) the sorting trays, movable, with 3 x 6 = 18 compartments in each, and (b) the container box.

The trays were pivoted back and forth to show the subjects that each tray was easily accessible. The trays were set within 1/16 of an inch between, closer than the figure shows.

Third, explicit directions, given in the same way to each subject, were as follows:

> "Look carefully at the blocks in the large container box. Now look at the movable trays. Notice the small boxes in each tray. In a moment you are to put one block in each of the small boxes in the trays, one in each, so that when you are through, all the blocks will be gone from the container box, and will be in the trays. Try to put them in so if you were asked to remember where each one was, you could find them with your eyes closed. Put them in any tray you care to. There are already two blocks in the trays. Can you see them? (points). They should not be moved. Begin when you are ready."

These directions were designed to promote a natural sorting response with no apparent structure as to pattern or sequence. The examiner allowed as much time as was desired by the subject, but in general subjects began within 10-15 seconds.

For each grade level 20 boys and 20 girls received the above directions and 5 boys and 5 girls received additional directions designed to sharpen discrimination, as follows:

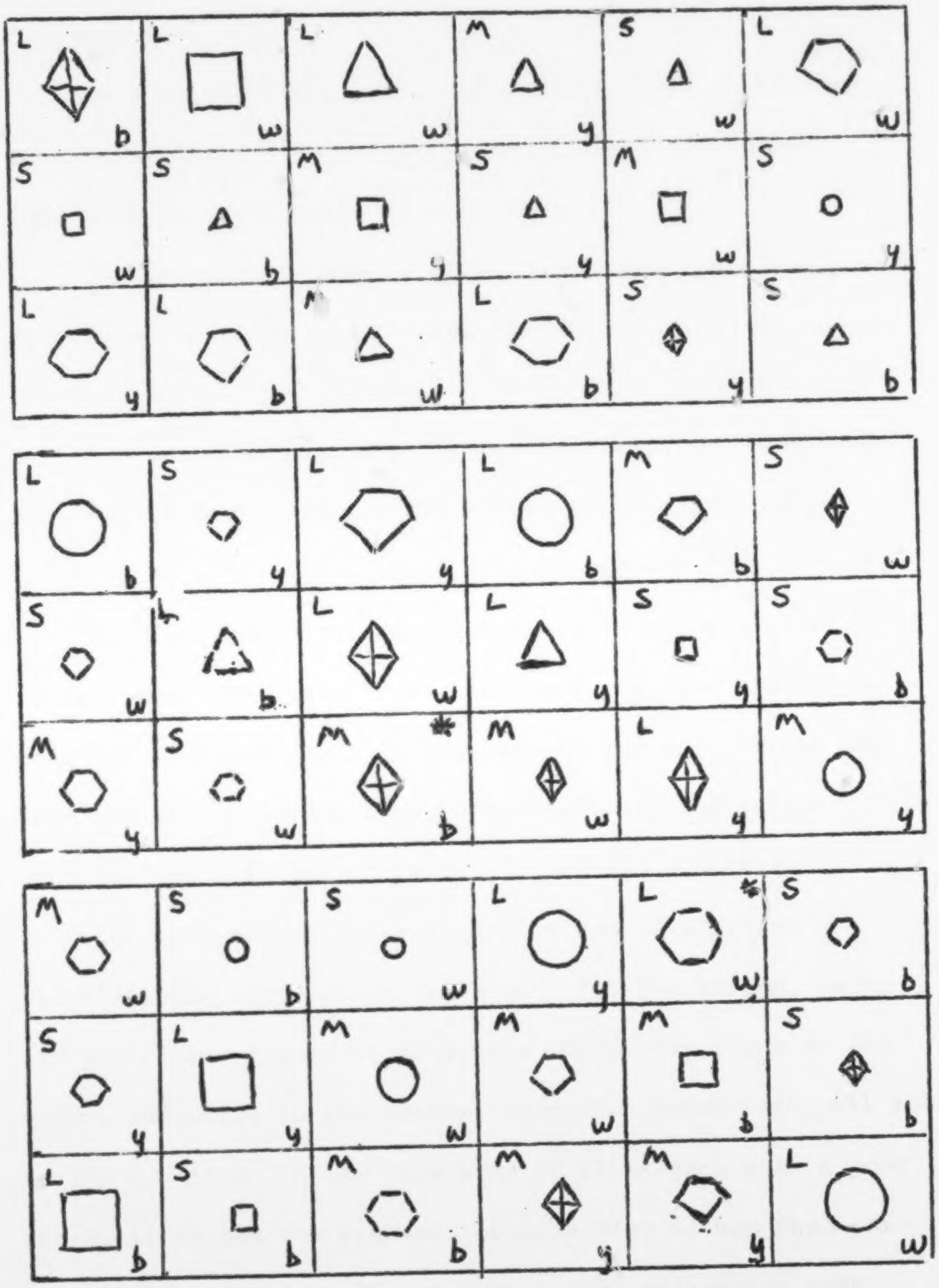
> "In the container box, how many kinds do you see? (pause) Place one of each kind on the table in front of the box. (Time was allowed until the subject had one of each). Alright, how many kinds are there? (pause) Alright, six is correct. Now, how many sizes do you see? Find one of each. (pause) Yes, there are three; large, medium, and small. Now, do the same for color. (pause)
>
> The following were used only on a special 9th grade group (S9) and an adult group (SA). Look at the movable trays, how many are there? (pause) How many small boxes in the front row of each tray? (pause) How many in each direction?"

After hearing both sets of directions, the D (discrimination) groups then proceded as the other groups. The S groups, as shown above, received more instruction regarding the nature of the trays before proceeding.

The Random Set

In Figure 4 3, a random set is shown. The objects have been equally spaced for easier reference. To obtain the set, the blocks were shaken and dropped. They were placed at random in the trays. They are displayed here to give some idea of how they might appear to a subject, and to give

Top


L b
L w
L w
M y
S w
L w
S w
S b
M y
S y
M w
S y
L y
L b
M w
L b
S y
S b
L b
S y
L y
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S w
M * b
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M w
S b
S w
L y
L * w
S b
S y
L y
M w
M w
M b
S b
L b
S b
M b
M y
M y
L w

Figure 4.3 A random set.

w=white
y= yellow
b= black

L = large
M = medium
S = small

the reader a chance to anticipate a possible solution.

The Solution

As a guide to the reader, the solution is given here as a frame of reference for the results and discussion, following in later parts of this paper.

The pre-placed objects gave an ultimate solution-structure such that considering all blocks together, only one best solution is possible. It is found in Figure 4.4

The solution requires (1) the principle of "increasing number of sides" to order the forms, (2) the grading and ordering by size, and (3) the grading and ordering of color.

With the medium-sized black-tehra in the center tray, three boxes from the left on the front row, and the large-white-ico (icosahedron) in the next to the last box on the last row of the bottom tray, ordering could logically proceed, and only one correct solution was possible.

The most common error by adults was to consider black for the second tray, and white for the bottom, using the pre-placed blocks in this way. Observing black in the middle and white in the bottom, they then began with all yellow in the top tray. While this kind of clustering gets a good score, it is not the highest, because size is not then completely accountable. If you have a full yellow top tray, and you have ordered also by size, what is now required on the second tray? A problem develops as seen :

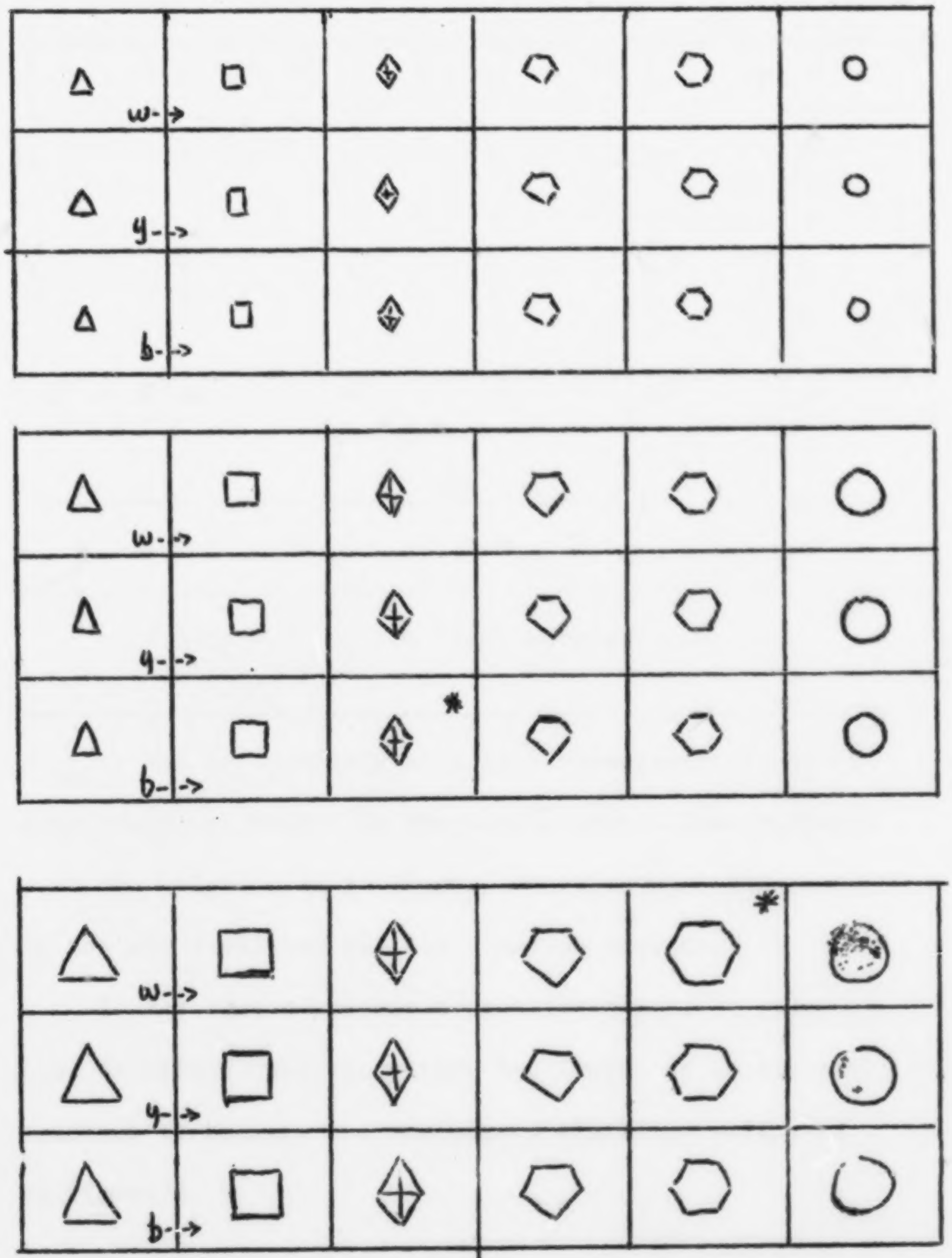


Fig. 4.4 The correct solution to the matrix sorting problem. (* pre-placed)

in Figure 4.5, since the medium size is in the front row.

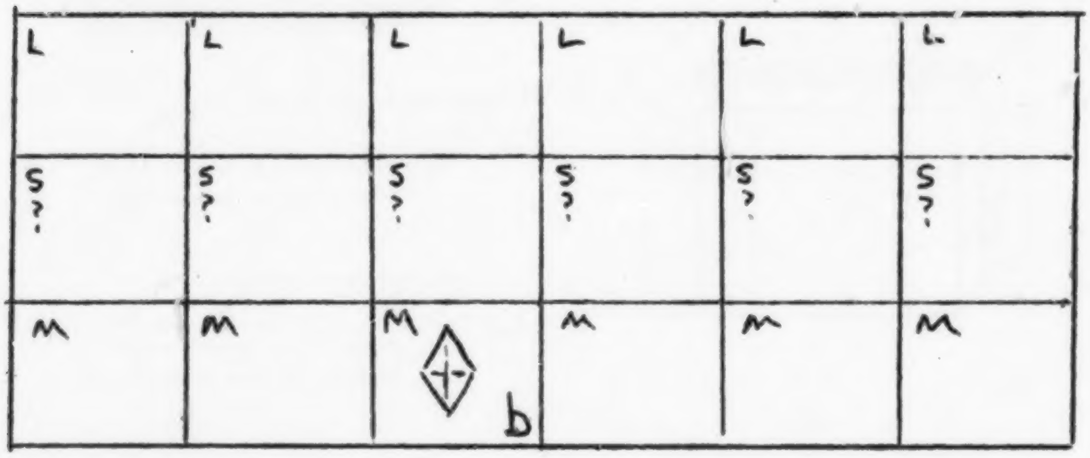
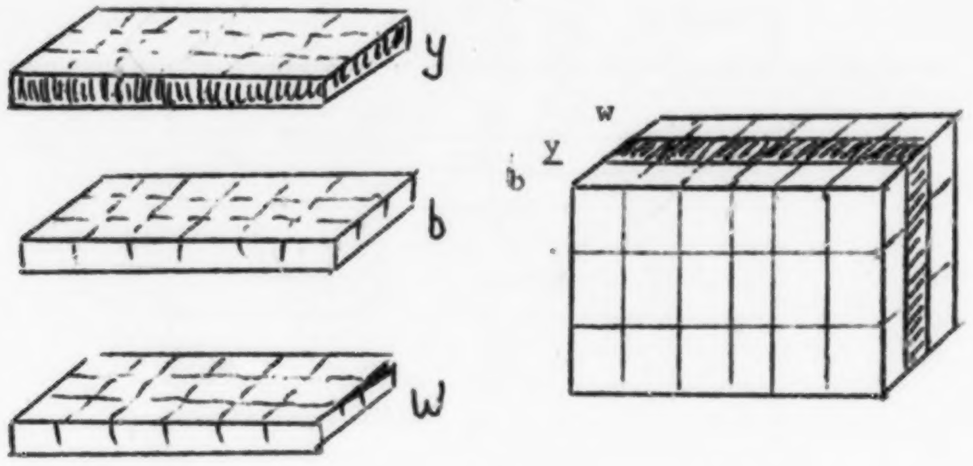


Figure 4.5. The black octa problem.

It was not possible with this arrangement to order size from S to M to L in the middle tray. Some subjects used the solution as in Figure 4.5 others used LSM only in the set involving the black medium octagon.

It was thus necessary to achieve a correct solution, too, in effect take the yellow top layer, as in (a) and sandwich it between the pre-placed black and white, as in Figure 4.6, b.



(a) (b)

Figure 6. Rotation of the yellow layer.

Thus, using the medium-black-octa in the second horizontal layer, and the large-white-ico in the bottom horizontal layer, the subject could observe a size ordering relation from small at the top to large at the bottom and still account for color.

Of course, scoring gave credit for intermediate solutions which did not require the above accommodation, but a perfect score was reserved for the solution as given above.

Subjects

The subjects were students from grades 1-9 inclusive as seen in Table 1, with one adult group.

Table 4.1 Number of Subjects by Grade

Grade	Male R	Male D	Female R	Female D
1	20	5	20	5
2	20	5	20	5
3	20	5	20	5
4	20	5	20	5
5	20	5	20	5
6	20	5	20	5
7	20	5	20	5
8	20	5	20	5
9	20	5	20	5
S9		10		10
Adult		14		14

A total of 9 x 20 = 180 males received regular instructions, and 9 x 5 = 45 males received instructions designed to increase discrimination. The same number of females were used, making a total of 360 regular and 90 D for a group total of 450. A special 9th grade group of 10 M and 10 F and a group of twenty-eight adults received additional instructions about the trays.

Although the original proposal called for approximately 45 at each level, it was possible to get 50. In addition, a special group of 9th graders and adults were added to try to establish some upper parameters.

All groups, except the adults, received the CTMM appropriate to their grade level. Since the short form CTMM does not include a spatial sub-test, all the 9th grade group was tested with the spatial sub-test of the DAT.

Two aptitude scores were used, the language IQ, and the non-language IQ. Both kinds of reasoning were important to the study, since verbal control has been emphasized in the literature as an important factor. The language section of the CTMM includes number problems, verbal comprehension, and delayed recall. The non-language section includes sub-tests on opposites, similarities, analogies, and numerical values. The kind of performance in the non-language section is perhaps at a more perceptual or "silent" level.

The testing schedule was circular by grades so as to keep students relatively spaced for maturity during the testing period. This meant that during a given week, a fixed number from each level was tested. During the six-month testing period, 1st graders, for example were part-tested with all other grades over the entire period. Otherwise, for a given grade, a 6 month performance differential could have occurred for a later group.

Scoring

Horizontal Color and Size. The scoring procedure was identical for both color and size, so we may use xyz to illustrate them. A template was set up for each layer, to focus on the pre-set stimulus as in Figure 4.7.Filled blocks were not used.

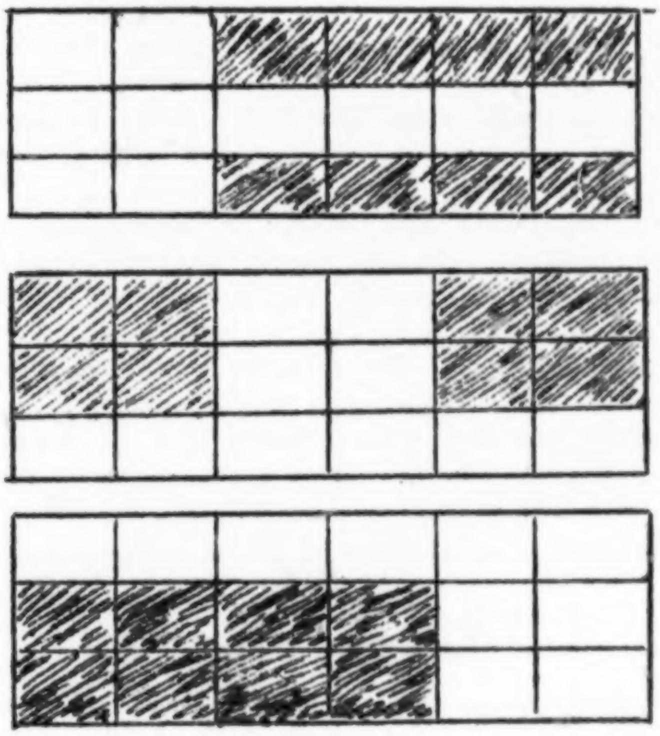


Figure 4.7 Scoring Template for Color and Size.

This scoring procedure produced usable comparative scores, and diminished somewhat the problem of considering permutations and combinations of the many clustering possibilities of 18 objects in each horizontal layer. Calculation otherwise would have been rather ponderous and un-focused.

General point distribution was based on an N-1 for each block and each line.

The scoring system is as follows:

(A) pairs -------------------- 1 pt (xx)
(B) trios -------------------- 2 pts (xxx)
(C) six of a kind ------------- 5 pts (xyz alternating)
(D) two sets of sixes --------- 10 pts
(E)* two sets of sixes which match correct solution ---- 12 pts. (Within block and line no blocks were counted twice, and the best observed combinations were used).

The (E)* score of twelve was obtained when all combinatoral possiblities fit the correct solution pattern in every respect, otherwise score is N points -1.

Using xyz for the three colors or the three sizes, examples of scoring are given below for the various patterns:

4.2

Table Two. Horizontal Scoring
For Lines and Blocks

Points					
1. Pairs					
xyyx	xy				xy
any single pair	xx				yy
	zy				yz
xx or yy or zz = 1 pt					
2. Trios					
xxx or yyy or zzz = 2 pts	xz	x-	xy	z-	three
or xyxzxy	yz	xx	xz	y-	different
	xz	-x	yz	x-	
3. xyxyxy xxyyy-	zx	yz	xz	zx	
xyxyzy xxxyy-	xy	xx	yy	xy	
yxyzxz xyzxx-	xz	yz	xz	xy	
4. xyzzyx (mirror pattern)	xx	xx	xx	xz	
xxxxyy xxxxyz xyxxyx	yy	yy	yx	yy	
xyyxyy	yy	xx	zx	zx	
5. Sixes (N-1)					
xxxyyy	xx	xx	xy		
xyzxyz (alternating trios)	xx	yy	xy		
xxxxxx (identity)	xx	zz	xy		
xxyyzz (three pairs)					
6. Sixes					
xxxxxx = 6 pts if blocks	xx				
were in the correct sol-	xx				
ution structure.	xx				

For a given tray, 12 points were possible or a total of 36 for a perfect whole solution.

Scoring is line score (L) plus block score (B); with

B	B				
B L	B L	L	L	L	L
B	B				

six for each, a total of 12 points possible. (two boxes are scored twice, one with L, one with B)

While necessarily arbitrary, progressively additional points are awarded for grouping of identities or alternates in increasingly complex form.

Inter-rater reliability is simply a matter of recording all varieties of scoring instances on the master scoring chart, and then using it as a reference. Patience is required, but not subjective judgement.

Horizontal Form

The scoring templates for form are seen in Figure 4.8

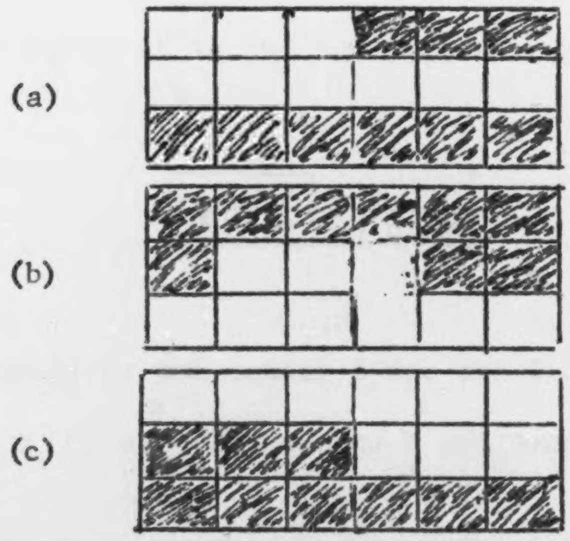


Figure 4.8 . Form templates, horizontal

As with color and size, B and L scores are added together. A new factor must be considered now, namely, form progressions. (It will be recalled that the blocks should be arranged in increasing number of sides). Since awareness of form progression is late in developing, scoring consisted of giving credit for different forms (shapes), whether in progression or not, up to N-1. A perfect score would be obtained for different forms plus proper progression.

The correct progression is indicated in Figure 4.9.

T Tetra	C Cube	O Octa	D Dodeca	I Icosa	S Sphere

Figure 4.9 - Form Progression

Points were awarded on the following variations:

(A) One point for each different form (object) used in the line minus one.

(B) Two points for each replication in the block of an object in the line -- but not for the same kind of pair twice minus one.

For example, if in the top tray the student had put

T	T	D			
T	T	O	C	D	D

his score would be 4-1 equals 3 for the line, since he used objects T, O, C, D. (The second T and Second D do not add to the score.)

For the block, his score would be 2-1 equals 1, since he replicated a T (the duplication does not count for the second TT pair). The DO gains no points.

His total score is then 4 points (L3 plus B1) for the top tray. The same procedure is followed for all trays to get the total, using the appropriate template.

Scoring for form is complicated in three ways:

(1) If the scoring were done as for color and size, we may be able to make some more directly comparable judgements as to the developmental appearance of these choices. For form and color of both identity scores, and difference (alternating objects) scores were used, which ever gave the most points.

(2) With this system, a line of identical forms is not given 6-1 equals 5 points, only 1 - 1 or 0 points. This means that identity scores are not used. We will observe later that a dip in form scores is due to a rise in identity scores. This gives an indication of a needed further exploration, since this suggests that students respond homogeneously to form, then heterogeneously, i.e., that identity grouping precedes progressions based on different forms.

(3) This means that the comparison of form to color and size must be restricted in this study to the particulary aspect of form which we have chosen to single out, in this case, progressions (varieties) in form, rather than group-

ing by identities.

(4) The total possible score is 36 for a perfect grouping, so, on the definition of form given in (3) above, some relative comparisons can be made with color and size. The main comparison involving form will be restricted to the discrimination-progression elements of form, i.e., how do students make use of the six different varieties of form?

Vertical Color and Size

Vertical scoring poses some additional problems. In this case we want to see whether or not the subject shows evidence of structure in tray 2 and 3 as compared to tray 1, and if possible, if it was done by design.

Again, color and size were considered as equivalent for scoring purposed, that is, the same scoring principles were applied to both.

The same template was used for all vertical scoring. Matrix layers used are seen in Figure 4.10.

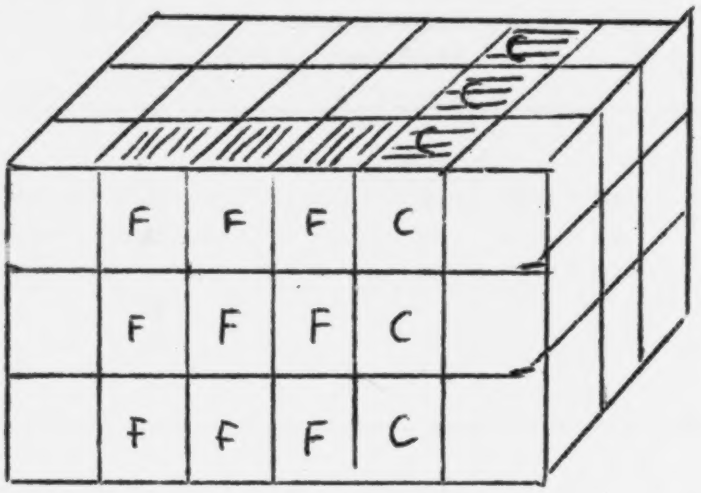


Figure 4.10 . Matrix Layers Used in Vertical Scoring.

The face block 'F ", a 3 x 3 unit, was scored first, then the cross face "C" was scored. Within blocks, units were used only once in the best observable combination.

For the face block, the nine x units were thus scored and multiplied by two, giving the possible perfect score of 18. For the cross block, a similar score of 18 was used in the same way, making a total possible score of 36, the same as for horizontal scoring.

The scoring patterns used are as follows:

Table Three (4.3)

Vertical Scoring, Points As Indicated Times Two:
Color and Size

1 Point			2 Points		
xz-	yx-	yzz	-x-	y-	xx
zy-	xz-	xyz	-y-	xy	yz
zz-	yz-		-z-	-y	xx
xy		xy			
zz		yx			
xy		--			

3 Points					4 Points	
xz	xy	corner	wb	bb	yxx	Pair 1, 4x's = 4-1
yx	zz	trios	wb	ww	yxx	
zy	yx		yy	ww	zyy	

For two sets of each diff.,
2 for first, 1 for second.

5 Points	
bbb	xxy
bbb	xxz
---	xxy
n-1=5	

6 Points
Same as (5) in structure,
but match perfect solution.
(B Y W, or S M L)

7 Points				8 Points	
sms	xxy	xxx	sls	yzx	unmatched
sms	xxy	yyy	mmm	yzx	to
sms	xxy	xxx	lsl	yzx	solution

9 Points		
bbb	if all matched	sss
bbb	to perfect	mmm
bbb	solution	lll

Note:
No points are given for two layer combination patterns, unless the same kind is seen in the next vertical box.
xyz
zyx equals 1 point for y's

Verticality is not always aided by the tray structure, but is used by those with a full-schema solution. It is possible for a subject to get a high score by simply repeating tray patterns without a direct awareness of verticality. Verbalizing the three organizing labels, color, size, and kind (shape) may also influence the result. Also, whether the trays swing (out of visual field), or pull in drawer fashion could be a factor in planned future variations.

Vertical Form

Scoring here is done with the same blocks as color and size, and the same template. As before, the focus is on the variety of blocks, but also credit is given where "layering" is occurring.

Scoring pattern are given in Table Four

Table Four (4.4)
Vertical Form Scoring Patterns

Front Face (x)				
1 Point	2 Points	3 Points	4 Points	5 Points
xx	x	xy	x in x	cc -co
--	x	xy	x column	oo or -co
yy	x	--	-	tt -co
xx				ccc (n-1)
-x				ooo
x-				---
6 Points	7 Points	8 Points	18 Points	
c- -	ccc	xxx	cod	Correct order
c in	-cc	xxx	cod	for 2 points
c c	-cc	xxx	cod	is cube, octo,
col.	2 + 5	(N-1)		Dodeco
Gross Face (y)				
Same as above, expect +2 credit for all icosohedrons which appear in the face.				

In scoring form, each unit in each block potentially counts 1 point, for a total of 18, but each object in the correct progression order is scored plus 1, or 2 points possible, for a full total of 36. Two correct items have to show horizontal continuity to receive 4 points.

```
C              C
X = 3          C = 4
C              X
```

The above assumes the c's have been placed in the cube column. This is done to give score credit to evidence of pattern in the solution as seen in replication.

The score in the front face is added to the score in the cross face for the total form score.

In the cross face, in the case of

CCC
SSS
III

six points are awarded instead of 8 because the student is using 3 objects in a context which requires a realization that six must be accounted for.

In the case of:

XYZ
XYZ
XYZ

the subject has ordered a particular item vertically, and has created a system worth N-1, or 8 points. If he later uses one form only

zzz
zzz
zzz

but it is not the required icosahedron, his score is also 8.

Common Objects Responses, Top and Bottom Trays

In order to observe the tendency to choose common objects, an evidence of "concrete" response, factorial analysis was made, grade by grade of cubes and spheres in the top, as compared to the bottom tray.

Size Responses, Top and Bottom Trays

As in the above, the aim here was to see if there is a tendency to use the larger (easier to pick up) objects first. The background problem has to do with the gradually developing superiority of logic over motor-perceptual convenience. This is one direct test of Piaget's stage theory.

True Zero, Relative Scores, and Equal Increments

When N-1 is used for scoring a structure short of the perfect pattern, it allows the correct solution to be scored and to appear distinctively in the data. Whether or not the application of N-1 allows for true equal increments of progress needs further research. For example, in scoring vertical form, N-1 is not used, for solutions short of perfect, but N+1 is used if the person has placed the block in the theoretically correct box. When a person gains insight as to form progression, in other words, his possible score for each of 18 units is doubled. While this technique quickly shows the coming of insight on this point, it may not show incomplete solutions up to that point without a kind of scoring-created plateau. In other words, the developmental trend may be masked by the scoring technique. As in many cases of this nature, some compromise seems necessary, since no equal increment techniques are available at this time.. What is necessary is that the decision be reported so that the necessary qualification may be observed. These kinds of problems have been referred to in the "continuous-discontinuous" learning controversy reviewed earlier in the literature.

True zero as absolute zero is a goal of measurement very difficult to obtain. In psychological measurement we usually have to be content with relative scores, and distances from a mean score. When first graders show (out of 36) a score of 15 on color, what does it mean? Have they come up from a prior, less effective state? One answer is to see what kind of scores one obtains from a random series. We might conclude, with some useful power, that scores above random are evidence of structuring. It is even conceivable that some preliminary forms of scattered structuring could cause a dip below initial random effort. Some of the graphs in findings will use this idea of a "random base", as a frame of reference.

Analysis and Data Processing

After, scoring, the data was processed, principally on the IBM - computor. Results are reported in the next part.

Part Five: ANALYSIS OF DATA AND FINDINGS

Objectives

The objectives of this study are: (1) to describe the developmental stages in age-level responses to color, form, and size, (2) to utilize the Bruner and Piaget systems to describe the stages, and (3) to observe if the stages are related to verbal and non-verbal aptitudes. Each of these will be done, with emphasis on the first objective, which was most time-consuming and most productive. A factorial design will be used rather than the chi-square analysis originally proposed in some segments, since the IBM became available during this period, making the more refined technique possible.

The Levels of Mental Ability

The first step in data analysis, assessing the C T M M (California Test of Mental Maturity) intelligence levels, showed a significant difference in grade level. The students, although selected at random, did not have equal intellectual ability grade by grade. For this reason, co-variance analysis was used in subsequent data processing.

Statistical Description of Age Level Responses to the Sorting Task

Age Level Differences

Table 5.1 gives the results of multivariate analysis using

Duncan's Multiple Range Test for significances utilizing the 1620 IBM computer. In the tables, "S" indicates significance at the 5% level or better.

Table 5.1a

Significant differences and means for sorting scores, grade by grade
Color sorting scores, horizontal

Grade	1	2	3	4	5	6	7	8	9	9S
1		n	S	S	S	S	S	S	S	S
2			n	S	n	S	S	S	S	S
3				n	n	S	S	S	S	S
4					n	S	S	S	S	S
5						S	n	S	S	S
6							n	n	n	S
7								n	n	S
8									n	S
9										S
$\overline{M}$	16.0	17.4	18.4	20.1	19.3	24.0	22.7	24.0	24.3	27.7

Table 5.1b
Color sorting scores, vertical

Grade	1	2	3	4	5	6	7	8	9	9S
1		n	n	n	n	n	S	S	S	S
2			n	n	n	n	S	S	S	S
3				n	n	n	S	S	S	S
4					n	n	S	S	S	S
5						n	n	n	n	S
6							n	n	S	S
7								n	n	S
8									n	n
9										n
$\overline{M}$	13.9	13.9	14.6	14.8	16.8	16.4	18.4	18.8	20.0	22.3

Table 5.1 c

Size Sorting Scores
Horizontal

Grade	1	2	3	4	5	6	7	8	9	9S
1		n	n	n	n	S	S	S	S	S
2			n	n	n	S	S	S	S	S
3				n	n	S	S	S	S	S
4					n	n	S	S	S	S
5						n	n	S	S	S
6							n	n	n	S
7								n	n	S
8									n	S
9										S
$\bar{M}$	16.9	17.0	16.8	17.5	18.0	19.1	19.3	20.7	20.6	25.6

Table 5.1d

Size Sorting Scores, vertical

Grade	1	2	3	4	5	6	7	8	9	9S
1		n	n	n	n	n	n	S	S	S
2			n	n	n	n	n	S	S	S
3				n	n	n	n	S	S	S
4					n	n	n	S	S	S
5						n	n	S	S	S
6							n	S	S	S
7								S	S	S
8									n	n
9										n
$\bar{M}$	14.7	14.1	15.1	14.0	14.1	15.1	15.1	19.0	18.9	19.0

Table 5.1 e

Form Sorting Scores and Means, Horizontal

Grade	1	2	3	4	5	6	7	8	9	9S
1		n	n	n	n	n	n	n	n	S
2			n	n	n	n	n	n	S	S
3				n	n	n	n	n	n	S
4					n	n	n	n	S	S
5						n	n	n	S	S
6							n	n	n	S
7								n	n	S
8									n	S
9										n
$\overline{M}$	14.7	13.9	14.3	13.5	14.0	14.3	14.2	14.5	16.7	18.5

Table 5.1 f

Form Sorting and Means, Vertical

Grade	1	2	3	4	5	6	7	8	9	9S
1		n	n	n	n	n	n	S	S	S
2			n	n	n	n	n	S	S	S
3				n	n	n	n	S	S	S
4					n	n	n	S	S	S
5						n	n	S	S	S
6							n	n	S	S
7								S	S	S
8									S	S
9										n
$\overline{M}$	3.7	5.3	4.7	5.0	5.3	6.0	5.3	8.1	11.8	12.5

The Random and Zero Base Problems

Because of the problem of finding a psychological zero, or even a random base, absolute comparison is not feasible. Scoring a random set of N=50, showed no significant differences between the random base, however, and 1st grade scores on any task.

The above data makes usable comparison possible in Guttman style, in the sense that we can clearly see the age levels at which differences begin to appear. The 9S group consisted of 20 ninth grade students given special instructions on discrimination.

Findings for Color, Size, and Form

Horizontal Color. In Table 5.1a, we observe the earliest significant difference to be between 1st and 3rd grade. The sixth grade is significantly different from all lesser grades. Seventh, eight, and nine grades are all significantly superior to fifth and all lower, but not to sixth.

Horizontal Size. Table 5.1 (c) shows that no significant differences have appeared until 6th grade, which then becomes superior to 3rd, 2nd, and 1st.

Horizontal Color-Size. It is clear that differences are appearing early in response to color, then to size.

Horizontal Form. Recall that horizontal form is concerned with utilizing different forms, and ultimately gaining a progression of forms in terms of increasing sides. It is a more particular definition of form than one which allows either identity grouping or progression grouping as done here.

Only spotted superiority appears for 9th graders when compared to 4th, 5th, and 2nd form differences. (5.1e)

An interesting follow-up study could more carefully explore identity versus difference grouping. In this study, some supplemental work indicated at the sixth grade level that identity scores develop first. In other words, Ss group like forms, before they select a series of different forms.

Vertical Color. There is a one year differential for vertical color, which as seen in Table 5.1b, where significant differences develop a year later or more than for horizontal color. Significant differences appear between 7th and 4th, 3rd, 2nd, and 1st.

Vertical Size. Differences here (Table 5.1d) begin to appear at the 8th grade (14 years of age).

Vertical Form. Differences here are somewhat similar as for size, beginning at 8th grade; but 8th grade differences did not include 6th grade. Also in 9S, differences extend to include 8th, where size went only to 7th. (Table 5.1f)

In Table 5.2, significance levels for the Horizontal and Vertical sorts are seen. Some evidence of dis-equilibrium at the seventh grade level as compared to sixth is to be observed, in the similar performance of 6th and 7th.

Table 5.2a
Significance patterns for total horizontal sorting

Grade	1	2	3	4	5	6	7	8	9	9S
1		n	n	S	S	S	S	S	S	S
2			n	n	n	S	S	S	S	S
3				n	n	S	S	S	S	S
4					n	S	S	S	S	S
5						S	S	S	S	S
6							n	n	S	S
7								n	S	S
8									n	S
9										S
9S										
Mean	47.6	48.3	49.5	51.1	51.3	57.4	56.2	59.2	61.6	71.8

Table 5.2b
Significance patterns for total vertical sorting

Grade	1	2	3	4	5	6	7	8	9	9S
1		n	n	n	n	n	S	S	S	S
2			n	n	n	n	n	S	S	S
3				n	n	n	n	S	S	S
4					n	n	n	S	S	S
5						n	n	S	S	S
6							n	S	S	S
7								S	S	S
8									n	S
9										n
9S										
Mean	32.3	33.3	34.4	33.8	36.2	37.5	38.8	45.9	50.7	53.8

As seen in Table 5.2 horizontal sorting scores for combined elements as a whole precedes vertical.

Significant differences for the final composite scores (total sort) are observed in Table 5.3. Scoring allows 12 points per tray, or 36 for one dimension such as horizontal color. Total horizontal points for color, size, and form = 36 x 3 = 108, and an equal total for vertical gives a total sort score possible of 216.

Table 5.3

Significance patterns for combined horizontal and vertical sorting scores; each grade compared to every other grade

Grade	1	2	3	4	5	6	7	8	9	9S
1		n	n	n	n	S	S	S	S	S
2			n	n	n	S	S	S	S	S
3				n	n	S	S	S	S	S
4					n	n	n	S	S	S
5						n	n	S	S	S
6							n	n	S	S
7								n	S	S
8									n	S
9										S
$\overline{M}$	77.9	81.6	83.9	84.9	87.4	94.9	95.0	105.1	112.3	126.1

This technique shows the development of significant differences as they appear for **combined horizontal and vertical sorting.**

Horizontal scores tend to develop before vertical.

Many reasons might be hypothesized for this, including the nature of the task itself. Students are used to working in a horizontal plane. Vertical organization at first may simply reflect another similar task (trays 2 and 3) in a new horizontal plane. Subjects push aside tray 1, (top) and, if following a plan, may replicate to some degree in the next tray for vertical scoring points. Attempts in this direction were given plus scores, although not until a full scale logical plan is developed can a perfect or near-perfect score be obtained.

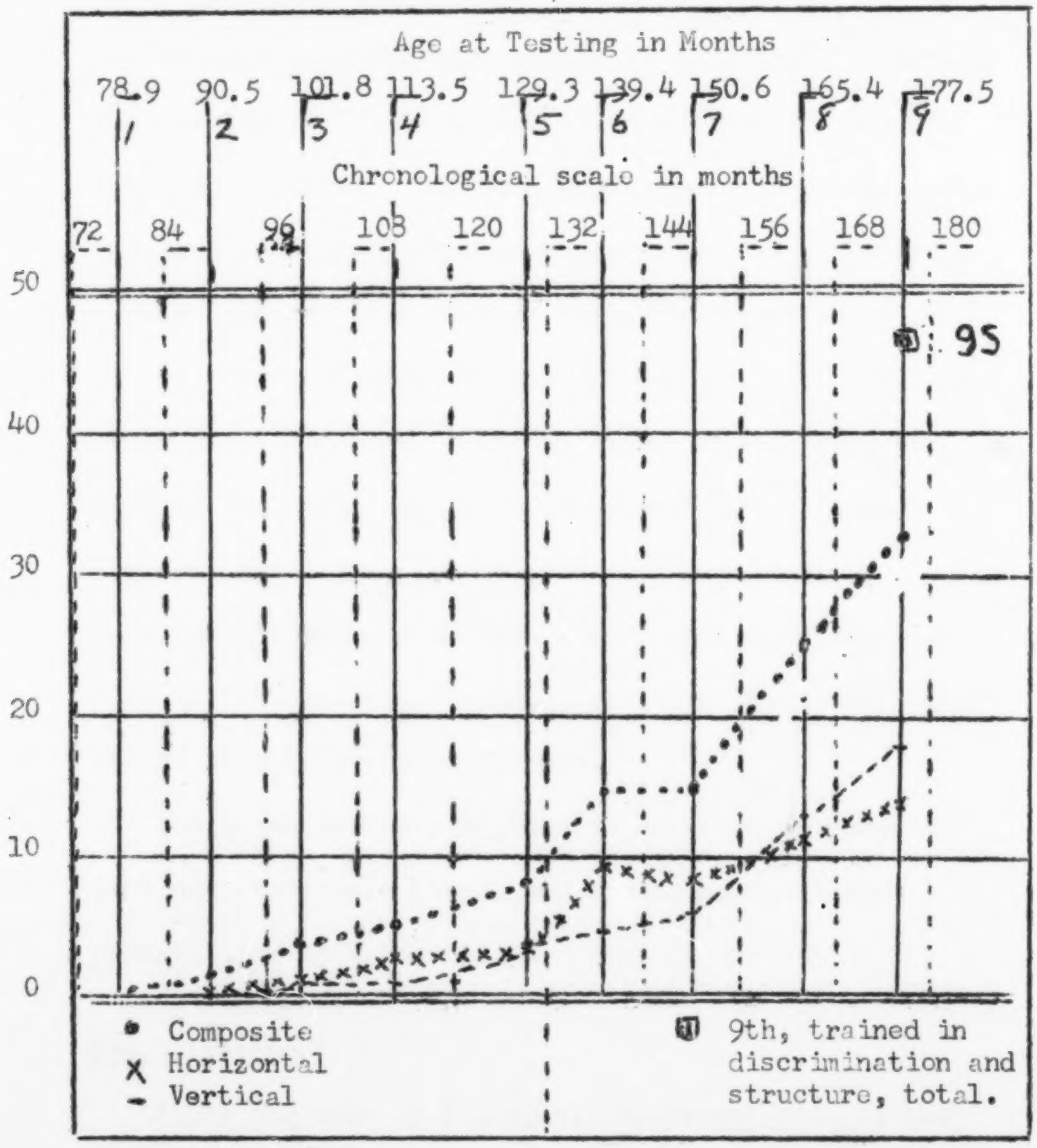
The procedure calls for a shift from color "levels" to color "slices". Note that this allows us to observe the over-riding of concrete replication by logical patterning. This point will be covered again later.

It may well be that a drawer-type device would show a different logical development, and could be an improved way of displaying vertical as related to horizontal organization. In such a structure, the hidden 2nd and 3rd drawers would be more comparably in each dimension.

A graphic representation of scores for horizontal color, size, and form development is seen in Table 5.4, as related to the actual months of age at testing.

Table 5.4

Selected rate of increase scores (with 1st grade scores as a base), plotted against actual months at testing



Note that while vertical rate increases over horizontal, the actual horizontal means are larger. the High 9S score shows the effect of training on sorting scores.

While the top score of 36 is possible in each element, these scores, as noted earlier, cannot be considered directly statistically comparable. They illustrate the general course of development, however, corrected for the mean age when tested.

Another qualification should be observed. Color and size scores reflected either attention to similarities or to differences. The form scores were based on mostly differences, since there were six varieties. The graph simply compares this kind of form with color and size as they were defined. We are not dealing with absolute color, size, or form. Further study is indicated for form on the basis of whether responses are different for familiar forms, as compared to less familiar. Labeling also seemed to have a differential effect, as seen in the specially trained groups in this study, which should also be explored further.

The graph in Table 5.4, then is only a supplement to findings previously given, and should be considered primarily as an illustration.

Sex Differences

Since the data in Table 5.5 is representative of the findings on sex differences, calculated tables for all the sub-areas for color, size, and form will not be included. It has already been shown that many differences between grades were significant; this is verified here as item B in the analysis of Table 5.5. It was found, however, that no sex differences appear in this experiment.

Also, no AxB interaction is noted. Therefore, sex differences do not appear in one grade and not in another.

Table 5.5

Analysis of Co-variance for Sex and Grade Differences in Matrix Sorting

Solution Vectors	df	S S	M S	Sig.
(1) A (adj.) (Sex)	1	6.9	6.9	N.S.
(2) B Adj. (grade)	8	36928.3	4616.04	1%
(3) AB Adj.	8	1401.4	175.18	N.S.
(4) Error	341	96833.1	283.97	

Hypothesizing on counter-balancing factors may in the furure be centered on verbal facility of girls, as compared to the added experience boys may have with regard to geometric forms.

A Description of Developmental Stages in Terms of the Systems of Piaget and Bruner

It is not a requirement, of course, in Piaget, that "formal" thinking be in matrix form. It only happens that taking three elements into simultaneous account in a matrix sorting problem such as the present one is a good illustration of "lattice" and "combinatorial" structure.

We have noted that by pre-placing two objects as in the present study only one correct solution to the problem is possible. This leads to a by-product which turns out to be an illustration of the Piagetian position. If a medium sized, black tetra is put in a position A, and a large, white ico (icosahedron) is placed in position B, an interesting thing occurs: a large propostion of adult subjects, using color, order by layer:

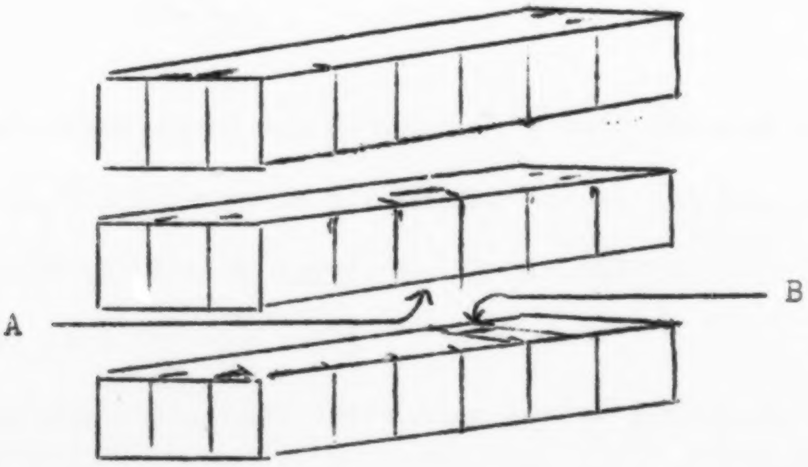


Figure 5.1 Position of medium, black tetra (A), and large, white icosahedron (B)

(yellow)
black
white

As logic begins to over-ride this initial concrete orientation, in order to accommodate size, as well, the S's change to putting colors in layers,

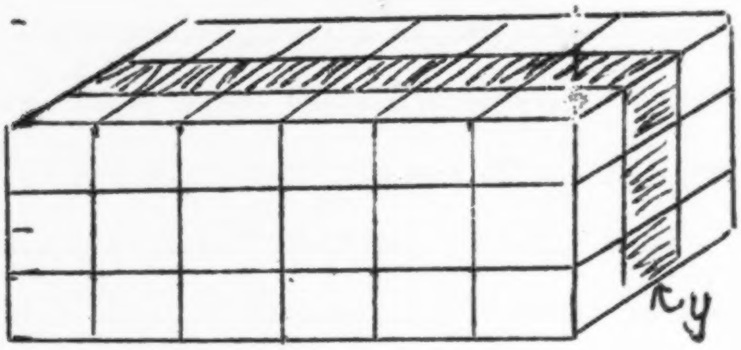


Figure 5.2 Yellow in a "layer" between the black in front, and the white in back.

so that size and color may be used in a co-ordinated fashion. (The median black tetra in the middle layer, and the large, white ico on the bottom layer, now order the logic so that "small" is used for the top.)

We may say then, that increasing scores represent shift from the "concrete" to the "formal" stage of development as described by Piaget. In this way, the scores reported in the preceding tables represent a fairly direct test of these stages.

It was pointed out in the review of literature that the Bruner terms for strategy "focusing" and "scanning" were related to the trial and check type of experiment, in which the critical attributes are pre-set by the experimenter. In such types of experiments, the S's are told after each trial whether the response is correct.

In developmental studies of the present kind, such is not the case, since the subjects work through the problem with a deliberate minimum of initial instruction, and no step-by-step correction.

In this case, an interesting reversal in theory use seems to be taking place. While Bruner found forms of "focusing strategy" most generally efficient, in the present experiment the reverse seems the case.

The reason is that progressive increases in scores can be described as involving a "scanning" strategy. In the present experiment, Ss must take into account three factors in a complex relationship. Focusing on any one aspect is poor strategy. The Ss do not progress unless they "scan", that is, work with the total set of variables. The data clearly show that Ss do focus on particular aspects first, and then gradually begin to scan as they formulate the logical relationships required. In this sense, "scanning" as in Bruner is similar to "decentering" as in Piaget. Successive focusing is **inefficient.**.

It is important to observe that the "lattice" structure is not a mere duplication of one solution replicated on the next level, because an "accommodative shift," requiring a logical structure is necessary in reaching a solution. This shift is the change in yellow, from a top layer. to a middle, vertical face.

We lack, in the present experiment, a way of finding this in the verbalizations of the subjects. (Inhelder and Piaget, 1958, p. 143) noted this limitation in the subjects being unable to generalize from an incomplete concrete solution. Also, Inhelder and Piaget (1958, p. 246) point out that in preoperational static states, subjects have not formed a single system and the orientation is primary perceptual. In concrete operations, Ss are organizing immediate sensory data. In formal operations they use higher-order labels, relatively independent of the particulars (Inhelder and Piaget, 1958, p. 249). Of particular interest for future study is the nature of the equilibrium in this kind of problem. Inhelder and Piaget (1958, p. 250) state: "...although each field of concrete organization easily attains stable forms of equilibrium, instability reappears when fields have to be coordinated." There is some evidence (Table 5.1) that Ss at the 7th grade level are experiencing some disequilibrium, since a drop in scores occurs. It may be that these students are trying to reorganize on a broader basis, thus temporarily causing a drop in scores attained by sub-system organization.

Concrete Responses to Size.

Using a factorial design, the variations in response to size were analyzed by observing the number of large objects in top, as compared to bottom trays. Behavior in pre-operational and early concrete stages suggest that larger objects would be utilized first, hence more in the top layer of the matrix. The results are in Table 5.6.

Table 5.6

Variations in the use of large blocks, cubes and spheres

	LL		CS	
Grade	Top	Bottom	Top	Bottom
1	7.4	4.8	7.9	4.9
2	7.3	4.5	7.6	4.6
3	7.9	4.7	8.7	4.2
4	9.5	5.0	8.9	3.6
5	7.6	5.2	8.0	3.8
6	7.2	5.4	9.9	4.0
7	7.6	5.1	9.5	3.7
8	7.2	4.7	9.9	2.8
9	7.6	5.2	8.8	4.1
S9	6.2	5.5	9.3	3.8
Adult	3.1	11.5	6.9	5.5
Perfect solution	0	18	6	6

It should be remembered that the situation required one large block to be pre-placed in the bottom layer. The persistence of the concrete tendency as shown above is very striking.

In this case, no change in balance was noted until the adult level. Since the logic of the solution required all large objects in the bottom, an almost complete reversal of the early "concrete" response was necessary. This empirical test of the development (1% level for adults) of a logical solution, or of a concrete II stage, shows that a solution does not occur during the ages studied, and that even the special training for 9th grade did not reverse the proportion as required.

Concrete Responses to Familiar Objects

Supplementing the above procedure, is the use of the same technique, using cubes and spheres, which are familiar as compared to less familiar forms.

As with size, the use of cubes and spheres in the top tray declines as a more systematized solution is achieved. Notice, however, that there is actually a trend in the wrong direction (away from a 6-6 balance) which persists through specially trained 9th graders. Only in specially trained adults does this concrete tendency shift toward a needed balance. This indicates that a future study could well explore these subtle factors in the 10, 11, 12, and early adult levels. Analysis of co-variance showed a significant (1% level) interaction effect as a result of the later shifts.

Here, again, the correct solution requires a different distribution of cubes and spheres than would be expected in the pre-operational or early concrete stages. The correct solution would show spheres in the last vertical face and cubes in the second face from the left, as shown in the correct solution, earlier.

Language and Non-Language Factors in Sorting Behavior

The CTMM gives a language score utilizing vocabulary and analogy. The non-language section is based to some degree on logical reasoning. The relation of these factors to the experimental task is in Table 5.7.

Table 5.7.

Correlations for L, NL, and Sorting Scores

Grade	L and Total	NL and Total
1	.007	-.01
2	.09	-.04
3	.06	.07
4	.03	.15
5	.08	.13
6	- .03	.09
7	.42	.52
8	.05	.22
9	.22	.33
All	.04	.14

Significance at the 5% level here required an r of .28, so only in the 7th, and 9th grades were r's large enough to show a significant relation. It will be noted that slightly higher correlations appear for non-language performance.

Since non-language, performance variables in this task could also be supposed to include spatial orientation, the spatial section of the DAT was given to the ninth grade group. The correlations in this case are seen in Table 5.8.

Table 5.8

The correlations between the DAT and various sorting patterns

Grade	Horiz.	Vert.	Total
9th	-.07	.11	.16
S9th	.12	.28	.21

Here, since N is relatively small, we must regard the results only as exploratory.

In this case, those in the regular procedure show negative and low r's, with some increased relation to vertical score. The same is seen for those 9th graders who were given particular training in observing the construction of the sorting binds as well as the blocks. Again, the relation is highest for vertical, though rather small.

The Effect of Special Training on Sorting Scores.

Ten students (5M, 5F) at each grade level were given special discrimination training on the objects. This training did not extend to the nature of the sorting trays; only for the color, size, and shapes of the objects. This did not include training on the nature of the trays themselves.

Table 5.9

Analysis of Co-Variance Showing the Effect of Discrimination Training

Solution Vectors	df	Mean Squares	F	Sign
Grade	8	4588.210	14.312	1%
Treatment	1	6855.217	21.384	1%
G x T	8	353.430	1.102	NS
Error	413	320.575	-	-

It can be seen that the simple device of calling attention to the varieties and sub-varities of objects produced significant effects, both as to grade level, and particularly for the training itself. No interaction was seen in GxT; that is, the treatment showed no special effect on any given grade.

Identity of Form, and Form Progression

In the present experiment, the emphasis and scoring for form was on progression. In other words, the subject, in order to increase his score, had to recognize the six different forms. He was not given credit for putting like forms (identity) together in horizontal scoring. He was given credit for using the six different forms, and for matching them to the sorting bin matrix, which also had six places. Additional credit was given for subjects who used the principle of a progressive increase in number of sides in their solutions.

The low form scores, in general, reflect the fact that differential use of forms of this kind (when color and size choices are available) develops slowly.

While not separated here, there was evidence to show that identity scoring would have allowed form scores to develop somewhat sooner. It was an arbitrary choice to use form differences with the ideas of bringing out this particular kind of development. Further study might show that putting like forms together, which develops 1st, attracts the effort of the student and inhibits the growth of progression scoring.

Some Parameters as Seen the Scores of an Adult Group

This segment demonstrated that it is possible to produce high and perfect scores by both matrix training, and form discrimination training.

The mean scores of the adults in this experiment on Total sort (horizontal and vertical combined) was 188.1 as compared to 112.3 for ninth graders.

The vertical total was 91.0 for adults and 50.7 for 9th graders.

The N for the adults was small (28), but the procedure did demonstrate that for several adults a perfect score (216) was possible. The high mean for the adults (188.1) resulted in part from explicit instructions to (a) carefully describe the objects, and (b) to carefully describe the nature of the trays and boxes into which the blocks would be placed.

Summary of Findings

1. In this sorting and classifying task, scoreable responses developed by increasing age, this order: color, then size, then form. Form was a more complicated variable including six varieties as compared to three colors and three sizes. In future experiments many varieties of these variables should be considered, including 3x3x3 matrices, with both simple and complex

forms and added varieites of colors and sizes. The initial formulation of the problem was based on the need to observe if subjects would make use of a six-box line to respond to six kinds of form more easily than a 3x3x3 which would not have allowed this focus. The fact that form still developed more slowly implies that the Ss did not quickly utilize the structure of the sorting bin in their solution.

2. Horizontal organization preceded vertical organization. This could have reflected the structure of the sorting matrix, which pivoted in a horizontal plane, suggesting that future work could test a drawer-type sorter. Since humansstore items in drawers in layers this may be a culturally determined response set.

3. Scores, in general, increased continuously with age, indicating a gradual overriding of concrete responses by logical formal system control required for a complete solution.

4. The discontinuity element observed at the 7th grade (they were lower than 6th) may reflect a disequilibrium due to an experience induced set to take more things into account. That is, they may have been more aware of the scope of the problem

to the degree that sub-systems were affected, but unable to achieve a system solution.

5. There were no sex differences in the solutions at any age level.

6. Discrimination training produced significant increases in performance. This implies that training may vary the emergence of solutions, rather than assuming maturation to be the basic factor.

7. Generally increasing scores at successive age levels gave evidences for progressive stages of cognitive development as described by Piaget, particularly for pre-operational, concrete-operational, and formal operational.

7a. Responses to large objects showed little decline until the adult level, indicating that the concrete quality response continues strongly during the period studied.

7b. Responses to the common forms, cube and sphere, showed the same pattern, indicating that a shift from concrete to formal stages occurred only after training an adult group.

8. Strategy changes are directly implied in the significantly increasing scores to the task requiring increasing use of three simultaneous variables.

Since the task solution required a co-ordination of elements, the term "scanning" strategy is more appropriate to describe success than is "focusing" strategy.

9. Early "centering" which Piaget uses to describe relatively immature behavior, was supplemented by addition of size and form with age increases, so that "decentering" accompanied increased success. This is consistent with his use of the term.

10. An analysis of the relation of language and non-language aptitudes to performance showed very modest correlations for Language I.Q. (.04 overall) and non-language (an overall r of .14) I.Q. scores. Out of the nine grades two significant correlations appeared for language aptitude and three for non-language.

11. The relation of spatial ability to the solution of the problem. When the DAT spatial test scores were correlated with the performance of the 9th graders, again, very small correlations were observed (r of .28) was the highest again for vertical sorting.

This would indicate that while spatial ability is a positive factor, that it is accounting for only a small proportion of the variance in this task.

Part Six: CONCLUSIONS AND IMPLICATIONS

Conclusions

1. In students of grades 1-9 inclusive, there is an increasingly systematized solution to a sorting problem involving 54 small objects of three colors, and three sizes of six forms. The order of development in the organized sorting of these objects into a 3x3x6 matrix was first color, then size, and finally form discrimination. Horizontal solutions appear first, then vertical for overall performance.

2. The increasingly formal and logical structuring of the score data may be interpreted as: (a) supporting a stage theory of cognitive development along lines proposed by Piaget, and (b) illustrating an increase in cognitive "scanning" strategy rather than "focusing" as proposed by Bruner, thus supporting the Piagetian position that maturity of cognition involves "reversibility" and "decentering", rather than focusing.

3. Maturity is more significant than either language or non-language variables. The non-language variables as measured by the CTMM (overall r was .14)

and the spatial section of the DAT show the highest observed relationship (Correlation for DAT and vertical sorting was .28.)

4. Discrimination training has a significant effect on performance. While no more effective at one age level than another (no interaction), training has a strongly facilitating effect on overall performance for all groups studied.

5. Performance may be improved by training either on the kinds and varieties of objects, or by training on the structure of the sorting bin matrix to be used for placing the blocks. Training in the structure of the sorting bin for a group of 20 ninth graders produced an r of .28 with the DAT spatial for vertical sort as compared to an r of .12 for horizontal. The regular ninth graders had an r of -.07 for horizontal and an r of .11 for vertical, indicating that spatial facility shows a positive, but low relationship to vertical sorting behavior.

6. The sorting task used allows the demonstration of levels of performance, with little evidence of "ceiling effect." The "concrete aspects" factor as seen in the excessive use of large and familiar objects in the top layer, does not disappear during the period studied, except for trained adults. Future work could be directed to a more detailed analysis of changes from 9th through 12th grade.

7. No sex differences were found on any of the variables, or combinations of variables.

Implications

Future studies should show differential responses to common as compared to less common forms. Results of studies like the present one represent the variable influence of context. Simple color discrimination develops in the sensory-motor period, but its use in a three variable context is another matter.

There is a limitation in the use of grade level scores as norms, on a task like the present one, since significant differences do not appear between each grade.

While the development as a whole seems relatively continuous, some discontinuities were observed. Whether these reflect states of developmental disequilibrium in the subjects of measurement and scoring effects needs further study.

Major differences appeared based on developmental or age-level factors; still, this was not wholly so, since these differences could be sharpened by task training.

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